CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 38 OCTOBER, 1952 NUMBER 4

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CALIFORNIA FISH AND GAME

VOLUME 38 OCTOBER, 1952 NUMBER 4

Published Quarterly by the
CALIFORNIA DEPARTMENT OF FISH AND GAME
SAN FRANCISCO

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MANAGEMENT OF CHAMISE BRUSHLANDS FOR GAME IN THE NORTH COAST REGION OF CALIFORNIA[1]

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INTRODUCTION

This study was begun in the spring of 1948 to investigate the possibility of managing chamise brushlands for game, the primary purpose being to determine whether game populations will build up under brushland management, and, if so, the most satisfactory way of manipulating the cover to increase game production. The investigations have centered mainly in Lake County, but have not been entirely limited to that area. In California, there are about 7,300,000 acres of chamise brushlands (Sampson, 1944). They are important in the interior Coast Range from Trinity and Shasta Counties south to San Francisco Bay. The chief center of their distribution, however, is in the southern Coast Range; smaller isolated units are found in the Sierra Nevada foothills. The chamise brushlands have been looked upon chiefly as valuable for game and watershed but little has been done in the way of management for either purpose. The rapid increase in population of the State, producing a corresponding increase in water demands, results in a greater need for good watershed management. Also more productive game areas are needed because there are more hunters and a greater need for meat, and as well a greater amount of time to be spent in recreation.

This paper should be looked upon as a progress report since the study is still under way and the results may change with a greater accumulation of data. It is recognized that more data are needed on nearly every phase of the project. The investigations are being carried on cooperatively between the University of California and the California Department of Fish and Game with funds provided by federal aid in Wildlife Restoration Act, Project California 31-R. Most of the wild life studies were made by R. D. Taber, the plant studies by the other investigators.

The authors express gratitude to the many persons who assisted in various ways on the project. The studies were suggested by Ben Glading, Chief of the Bureau of Game Conservation, California Department of Fish and Game. He foresaw a need for information of this sort in developing sound game management policies for the Bureau of Game Conservation. Dan Tillotson, also of the California Department of Fish and Game, has been in general charge of Pittman-Robertson projects and helped in many ways. Many students in the University of California helped at various times. Professor R. E. Storie of the university examined the soils, and Dr. J. Vlamis made the soil fertility tests. The food analyses of deer stomachs were made by Carol Ferrel and Howard Leach of the fish and game

[1] Submitted for publication April, 1952. Federal Aid in Wildlife Restoration Act Project California 31-R.

laboratory in Berkeley. Merton Rosen, Arthur Bischoff, John Azevedo, and Alvin Hightower assisted in collecting the deer and making parasite examinations. Gratitude is expressed also to ranchers in the area for their generous cooperation, and especially to Glen Keithly for the benefit of his keen observation and the information he gave on brushland management. He is a pioneer in this work, having started a program of brush control for sheep and deer years earlier. Much of the work presented here was done on Keithly's ranch.

Appreciation is expressed to the following who critically read the manuscript: Keith Arnold, H. F. Heady, W. E. Howard, A. S. Leopold, W. M. Longhurst, R. M. Love, A. W. Sampson, K. W. Wagnon, University of California; W. P. Dasmann, Ben Glading, Dan Tillotson, Department of Fish and Game; L. T. Burcham, State Division of Forestry; F. P. Cronemiller, M. W. Talbot, U. S. Forest Service; R. M. Bond, Soil Conservation Service; G. H. Sharrer, Bureau of Land Management; E. N. Dye, Ralph Leavers, California Farm Bureau; N. M. Hughes, Associated Sportsmen; Glen Keithly, rancher.

DESCRIPTION OF CHAMISE BRUSHLANDS

The brushlands studied are typical of western Lake County and much of the North Coast ranges. Data on vegetation, soils, and climate are taken from the study areas, or nearby, but are applicable to a much greater range.

Vegetation

In general the chamise brushlands in Lake County comprise two cover types, those in which chamise (*Adenostoma fasciculatum*) predominates and those which contain a mixture of broad-sclerophyll shrubs and small

FIGURE 1. Close view of chamise brushland in Lake County. Chamise predominates on the south-facing (S) exposures while a mixture of taller broad-sclerophyll shrubs and small trees are found on the north-facing (N) slopes. Lake County brushlands have long been famous deer hunting grounds. Water from springs is well distributed in the ravines.

trees. The chamise occurs mainly on south-facing slopes and drier sites while the mixed chaparral is found on the more mesic north exposures and in ravines (Figure 1). This intermixture of chamise and mixed chaparral is especially favorable for deer. A majority of the shrubs and small trees are good or excellent browse species. The intermixture of browse plants in Lake County is probably as favorable for deer as most chamise brushlands in other portions of the State. Some brushlands are so nearly pure chamise that they furnish relatively poor browse.

On south exposures in Lake County chamise often occurs in relatively pure stands, depending primarily upon the age of the stand and fire history, but usually it occurs with admixtures of lesser amounts of wedgeleaf ceanothus (*Ceanothus cuneatus*), wavyleaf ceanothus (*C. foliosus*), Stanford manzanita (*Arctostaphylos stanfordiana*), poison oak (*Rhus diversiloba*), yerba santa (*Eriodictyon californicum*), and others. The ceanothus species above, which are nonsprouters, are in greater abundance in young or recently burned chamise stands that have not been repeatedly burned in close succession.

The north-facing slopes are vegetated chiefly by interior live oak (*Quercus wislizenii*), scrub oak (*Q. dumosa*), Eastwood manzanita (*Arctostaphylos glandulosa*), California laurel (*Umbellularia californica*), toyon (*Photinia arbutifolia*), birchleaf mahogany (*Cercocarpus betuloides*), deerbrush (*Ceanothus integerrimus*), chamise, and others, roughly in that order of abundance. Interior live oak frequently makes up half of the cover.

Other species may predominate or become more important in special sites. In wetter situations, madrone (*Arbutus menziesii*) and canyon live oak (*Quercus chrysolepis*) are common. Knob-cone pine (*Pinus tuberculata*) is frequent on certain soil types. On ridgetops chaparral pea (*Pickeringia montana*) is more abundant than on either north- or south-facing slopes.

The brush canopy on all sites is usually so complete as to preclude much herbaceous vegetation as understory.

Soils

The soils on south exposures where chamise occurs in the study areas are derived from consolidated sedimentary rocks. The shallower and least productive ones have developed on parent materials which have undergone the least metamorphosis. The Maymen series is typical of this group and occurs most extensively. These soils are less than 12 inches deep and are light brown in color, moderately acid, and vary from clay to clay loam in texture. They are relatively low in fertility. Soils of the Dorado series, which usually occupy the lower edge of the chamise slopes, are formed on sediments having undergone an intermediate amount of metamorphosis. They are deeper than the Maymen, 12 to 18 inches, less acid, and light reddish-brown in color.

On north exposures the soils are generally deeper and darker in color than those on south exposures. Some are a deeper phase of Maymen, ranging in depth from 12 to 24 inches. The Los Gatos series, intermingled with the Maymen and usually supporting a mixed stand of brush with occasional knob-cone pine trees, are soils developed on the more highly metamorphosed sediments and are general underlain by more

massive rocks. They are 18 to 24 inches in depth, moderately acid on the surface, and are reddish-brown in color. Laughlin soils may occur where chamise contacts or invades into woodland-grass. This series is characterized by depths of 24 to 30 inches, medium to fine texture, and slight acidity. The soils are light brown to light reddish-brown in color and are formed on residual parent material. They are relatively fertile soils and support fairly heavy stands of herbaceous vegetation where the brush is removed or thinned out.

Soils from the study areas were tested for fertility by using pot tests conducted in the greenhouse by the Soils Division of the University of

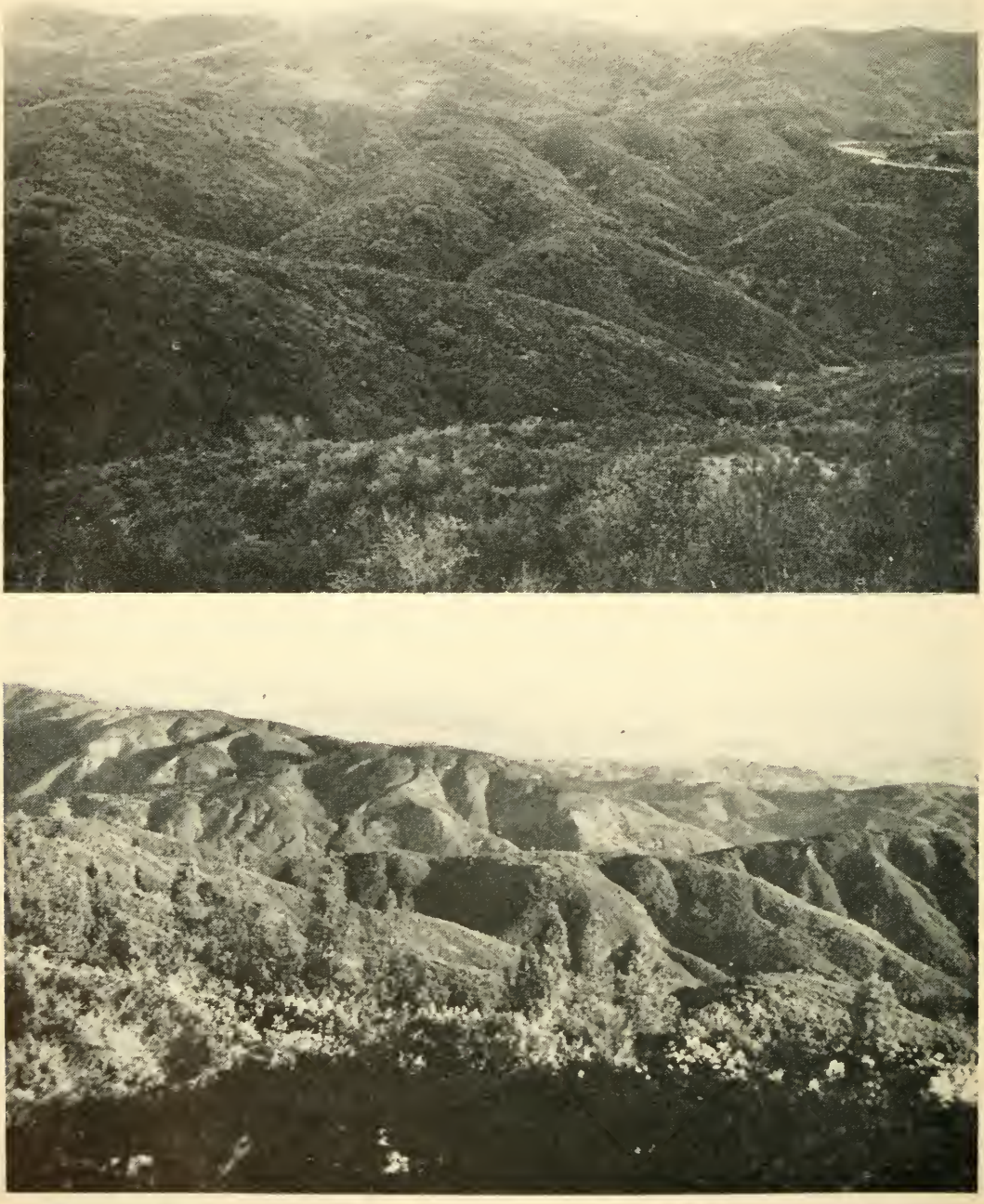

FIGURE 2. Chamise brushlands in Lake County. Some are not excessively steep while others are rugged and somewhat inaccessible.

California at Berkeley. Results of these tests indicate that chamise-covered soils are generally low in nitrogen even when the woody vegetation has not been disturbed over a long period of time.

It is generally recognized that a majority of chamise brushland soils are low in fertility. On the study areas the Maymen soil was the most extensive and least productive; perhaps it forms a larger area than any other chamise brushland soil in California. Probably the second most extensive chamise brushland soil in California is Los Gatos. This is considered more productive than Maymen. Another frequently occurring chamise soil, perhaps the third in rank, has not yet been named but contains a large amount of granitic material. The fertility of the latter soil is considered about the same as that of Maymen. Serpentine soils are about the poorest of all. Chamise also occurs on several other soils, a majority of which are more fertile than those named above. Some are relatively deep and have been cleared for agricultural crops.

Slopes where chamise occurs are generally rather steep (Figure 2). On the study areas in Lake County they averaged about 20 to 25 degrees. In some chamise brushlands the average slope is greater,

Climate

The weather station nearest to the study areas is at Lakeport, on the west shore of Clear Lake, about three to eight miles away. The mean annual temperature recorded there is 57 degrees F., the extremes varying generally from about 20 degrees to 110 degrees.

Mean annual precipitation, based on a 30-year average, is 28 inches. Practically all of this comes as rain between late September and April, inclusive; consequently, the summer months are extremely dry. Since the vegetation becomes very dry during summer, the possibility of large acreages of brush being destroyed by fire is high. Water becomes less abundant along drainage ways as the dry season advances but many of the springs maintain their flow throughout the summer.

The same general pattern of temperatures and rainfall characterizes all chamise brushlands in California. The brushlands usually occur where the precipitation is between 14 and 40 inches. Where rainfall is 14 inches and below the chamise becomes open and desert-like in appearance and above 40 inches it generally gives way to forest growth. In areas receiving between 14 and 40 inches of rainfall the soil is apparently more important than climate in delimiting chamise brushlands.

PRESENT LAND MANAGEMENT PATTERN

Chamise brushlands have been generally looked upon as valuable for game and as watersheds. Some are used in sheep production. They are more suitable for sheep than cattle because of steepness of slopes and the predominance of browse. Poisonous plants occur on many chamise brushlands. Little effort has been made to manage these lands.

Usually the intention of public agencies has been to protect chamise brushlands from fire, but, in spite of this, wildfires occur frequently (Figure 3). Some of the wildfires have been large and destructive (Figure 4). Some people wonder if large fires are not to be expected where total protection is attempted. As a result of protection the brush is permitted

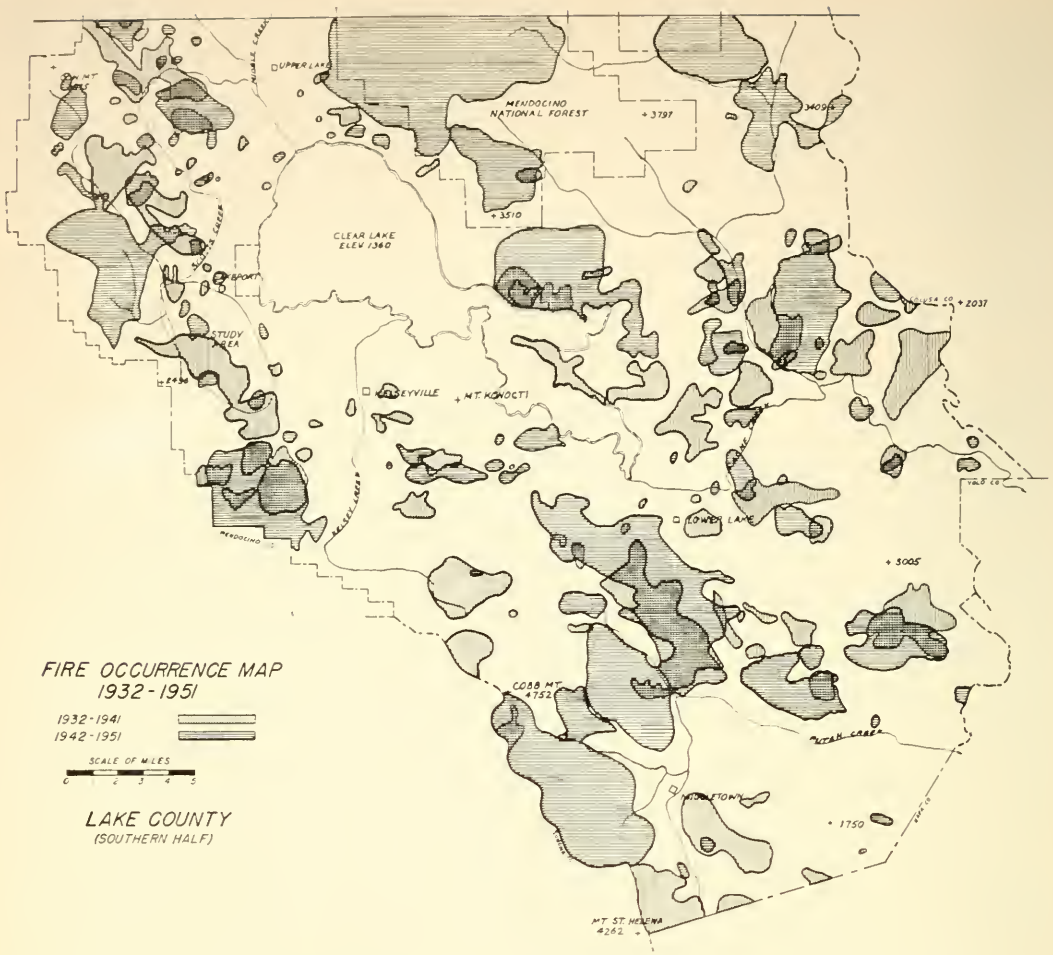

FIGURE 3. The shaded portions indicate areas burned by wildfires. Much of the unshaded portion is agricultural land. It appears that a majority of the brushlands in the southern half of Lake County burn at least one time in each 20 years. Fire records were furnished by the State Division of Forestry. The map does not show all of the fires but attempts to show all the area burned at least once by wildfires in each of the 10-year periods.

to grow up uniformly and within about 25 years much of it becomes dead fuel; this material greatly increases the fire hazard. When fires are started in this kind of cover they are difficult to control and are likely to be large and destructive. Limited "spot burning" in the spring months has been suggested as a means of reducing the hazard of such fires. In fact, burning of this nature was initiated in Lake County in 1950-1951 by personnel of the county board of supervisors, State Division of Forestry, county farm advisor, Fish and Game, and private landowners. Plans call for limited burning in the spring to reduce fire hazard around cultural developments and also to decrease the possibility that large wildfires will occur during summer. Another purpose of spot burning is to improve conditions for game.

Areas burned by wildfires are usually not reseeded and the soil is nearly bare the following winter. In the second winter the soil is fairly well covered with sprouts and brush seedlings. Then within 8 to 12 years the brush stand is well developed and becomes nearly impenetrable. During these years little dead wood or litter is produced and fire presents no particular problem (Buck, 1951). If it were not for this period of

FIGURE 4. Wildfire burned area of 6,000 acres in Lake County. Wildfires are frequent and often large and destructive. In this case the fire burned so intensely that insufficient unburned brush remained as cover for game.

reduced fuel following wildfire burns in dense brush, fires would probably occur more frequently than at present and would also be larger and more uniform in intensity.

Game populations in or around wildfire burns usually build up while the brush is young and palatable but then decrease or move out when the brush grows up. Of recent date controlled burning and other manipulation of brush to improve conditions for game has gained popularity. Some areas are reseeded to herbaceous plants and managed following brush removal; some are not.

There has been some question as to watershed conditions under chamise brush and the effects of fire on erosion. Investigations by Veihmeyer (1951) have shown that small plots burned annually convert largely to grass and in this condition there is less erosion than from undisturbed areas of chamise. Studies by Colman (1951) and others have shown that erosion accelerates following occasional brush fires in chamise and may continue for at least eight years. The latter studies were in areas not reseeded to grasses, where little herbaceous vegetation occurred. Both sets of studies would indicate that chamise is a relatively poor watershed cover, especially since such brushlands burn frequently. More studies are needed on the feasibility of converting chamise brushlands to a cover better adapted to prevent erosion. Both grass and trees offer considerable promise for this purpose but studies on the possibilities of manipulating vegetation to improve watershed conditions have scarcely begun in California.

It has been observed many times that the surface soil is loose following fires in dense brush and is easily moved downhill by deer feeding over slopes. On steep slopes considerable soil may gradually be moved to the bottoms of drainageways. This is washed away during winter storms. On the other hand, the soil is usually firm in areas of burned grass and little movement takes place. Again, the observations indicate that grass shows

promise of lessening soil erosion in the presence of fires. Differences between grass and brush covers may be summarized as follows: Fires in grass are less intense than those in brush; the grass seeds and residue are not all destroyed; the grass begins growth following fall rains and soon covers the soil; the soil is firm following fire. In dense brush, on the other hand, the fires are intense; the soil is loose and bare the following winter; the shrubby vegetation recovers slowly.

GAME POPULATIONS AS RELATED TO BRUSHLAND MANAGEMENT

Game populations were studied in Lake County under three different conditions of chamise brushland: (1) Heavy brush cover protected from fire; (2) Wildfire burn, in which there were a few unburned islands the first winter, followed by the presence of brush sprouts, seedlings, and a small quantity of herbaceous cover the second year; (3) Opened brush, consisting of small burned patches within dense brush seeded to suitable herbaceous plants (Figure 5). Area of each condition was about 1,000 acres.

Detailed investigations were made on the Columbian blacktailed deer (*Odocoileus hemionus columbianus*). During the course of this work observations were made of the California jackrabbit (*Lepus californicus*), brush rabbit (*Sylvilagus bachmani*), mountain quail (*Oreortryx picta*), valley quail (*Lophortyx californica*), and mourning dove (*Zenaidura macroura*).

Deer Populations

The deer of this region are resident rather than migratory, but they do make short seasonal movements which depend on weather conditions and food supplies. Population densities were determined by pellet censuses checked by sight records. The number of deer on the study areas in heavy brush ranged from averages of 10 to 30 to the square mile, in the wildfire burns from 5 to 160, and in the opened brush from 40 to 110. Where surrounding food conditions are poor, a wildfire burn of newly sprouting brush will attract large numbers of deer. However, all of these deer may move to better cover in bad weather; also, the burned area loses its attractiveness very rapidly as the sprouts grow up and become less palatable. Over a period of years extensive wildfire burns support lower average deer populations than opened brush because there may not be enough deer to keep the sprout growth in a palatable stage.

Search for basic factors governing deer population densities in the different brush covers included the investigation of fawn production, the weights or relative condition of individual deer on the three study areas, and food habits and comparative nutrition.

Fawn Production

Studies on collected does indicate that fawn production is governed largely by ovulation rate. Ovulation rates in adult does (18 months and older) were approximately as follows: In heavy brush, 84 percent; on wildfire burn, 116 percent; in opened brush, 147 percent (Taber, 1953). Although the doe collection consisted of only 42 individuals, reliance on these figures is strengthened by the fact that they correspond closely to

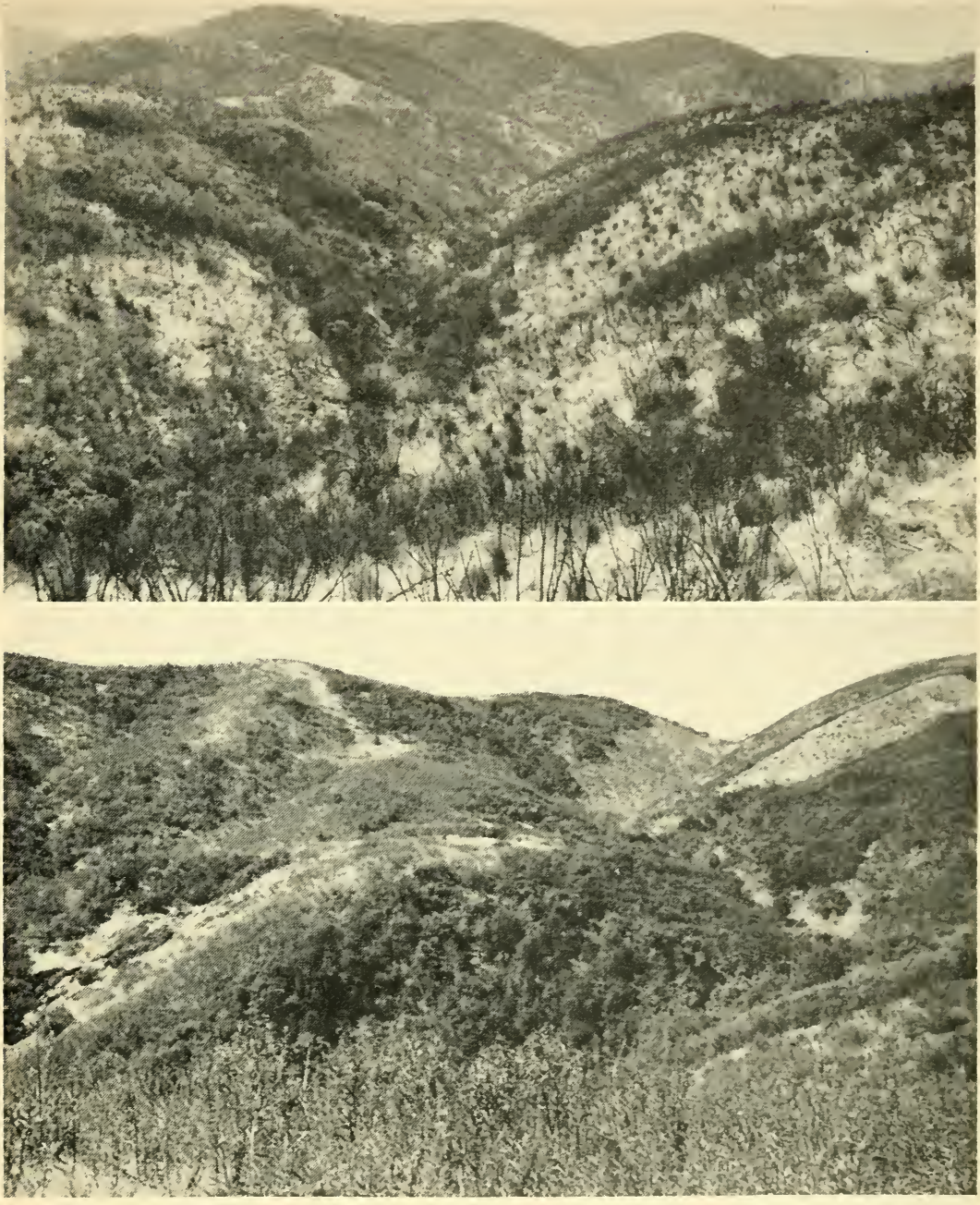

FIGURE 5. Areas of opened brush produced by spot burning. The interspersion of grass and brush forms a favorable habitat for deer. During late winter and early spring the deer graze heavily on the grasses. The spots of dense brush form necessary cover.

the ratio of fawns to 100 adult does following the rut. This ratio varies somewhat from year to year, but the following values seem to be representative for the areas under study: in heavy brush, about 60 to 85 fawns per 100 adult does; on the wildfire burn about 100 to 110 fawns per 100 adult does; in opened brush, about 115 to 140 fawns per 100 adult does. A change in the fawn : doe ratio between the fawn drop and the rut obviously may be brought about by either fawn or doe mortality. Therefore the ratios do not necessarily represent an extremely high fawn survival. Actually there is evidence of some mortality among both does and fawns during the summer.

Deer Weights

Skeletal size differences between deer of the same age for the different brush cover conditions seem to be either small or absent. Therefore, comparing weights of deer of the same age gives an indication of relative condition rather than comparative size.

The weights of 23 bucks taken from the heavy brush and the opened brush during the hunting season are compared in Table 1. The bucks are grouped by antler beam diameter, the first class (15-19 mm.) containing mostly young bucks and the second class (19.1-23 mm.) containing those of medium age. Weights were obtained with the paunch out but all other organs present.

TABLE 1

Field-dressed Weights of 23 Bucks From Two Conditions of Brush Cover, 1949
(.2 Level of Significance)

Beam diameter	Heavy brush		Opened brush	
	Weight, pounds	Number of deer	Weight, pounds	Number of deer
15-19 mm.	66.0±3.73	9	75.5±4.99	6
19.1-23 mm.	81.0±7.7	5	86.5±6.66	3

Bucks from opened brush tend to be heavier than those from heavy brush with this tendency being greater in young than in medium-aged deer. The bucks from a recent wildfire burn tend to be about as heavy as those of similar age from opened brush. They also tend to have more massive antlers.

A sample of does taken in late winter and early spring indicates that those from opened brush tend to be in the best condition, those from the wildfire burn intermediate, and those from heavy brush poorest. This difference is most distinct in yearling and very old does and less so in those of medium age.

Food Habits and Nutrition

The deer in opened brush have access to much more herbaceous forage than those in the wildfire burns or those in the heavy brush, and their diet consists largely of herbs in the late winter and early spring.

In the interpretation of results, it should be remembered that the browse species start rapid spring growth in April, putting forth many succulent sprouts. In the opened brush it may be seen that herbaceous forage was preferred during February and March, and that browse consumption rose during April and herbaceous species were taken heavily again in May. Thus where the deer had both woody and herbaceous plants available they seemed to prefer the more succulent forage. In the wildfire burn, where there was much less herbaceous forage, the deer tended to take herbs whenever available except in April when the tender brush sprouts were emerging. In the heavy brush, herbaceous material was practically absent and the deer had to subsist on browse, regardless of preference. These findings illustrate that herbaceous plants are heavily

TABLE 2

Summary of the Food Habits on Each Area for the Late Winter and Early Spring Months

	Brush type											
	Heavy brush				18-month-old wildfire burn				Opened brush			
Month	Feb.	Mar.	Apr.	May	Feb.	Mar.	Apr.	May	Feb.	Mar.	Apr.	May
Number of deer	3	3	3	10	5	4	6	1	5	4	5	3
Percent volume Herbaceous	2	3	1	5	1	41	1	65	70	97	50	86
Browse*	98	97	99	95	99	59	99	35	30	3	50	14

* Including acorns.

utilized during late winter and spring when most succulent. The nutritional intake of deer which have abundant herbaceous forage appears to be highest. Mature browse is of low nutrient value compared to growing herbs, except for a short spring period of rapid growth (Gordon and Sampson, 1939). This is especially true of nondeciduous browse species such as chamise, interior live oak and wedgeleaf ceanothus, which were among the staple browse plants in the study areas. During late summer and fall the deer on all areas subsist largely on browse. Analyses have shown that crown-sprouts of chamise on burns have a higher nutritional content than older growth stages of the same plants (Reynolds and Sampson, 1943).

While the whole question of nutrition has not yet been thoroughly explored, there is evidence to indicate that the opened brush and the heavy brush may be compared for annual diet in the following manner: In the opened brush, the deer have available an excellent diet during four months of the year, foraging on abundant herbs and new sprouts (February-May), a good diet for another four months (November, December, January, June) when some green herbs are available and sprouts are still growing in the spring and early summer, and a poor diet during the remaining four months (July-October) when the herbs are dry and the browse plants are more or less dormant. In the heavy brush the deer have access to an excellent diet only two months of the year (April, May) when the brush is growing rapidly, a good diet during two months (March and June) when there is some shrub growth, and a poor diet for eight months (July-February) when there is little growth and the shrubs are largely dormant. In a wildfire burn the amount of succulent browse available in winter depends on when the area burned. If the fire is very late in the season there will be practically no crown sprouting until the following spring.

The difference in nutritional planes is probably based on adequacy of assimilable protein and phosphorous in the opened brush and a lack of these elements in the heavy brush. The basis for the differences in population density, fawn production, and condition of individual deer among the various brush cover conditions is probably to be found in differences in nutrition of these cover types.

Resident Small Game Populations

The small game population density estimates given below are based on strip-counts and observations for the quail, pellet counts for the jackrabbit, and general observations for the other species.

Valley Quail. In the heavy brush and in wildfire burns the valley quail population density in late summer seems to be about 100 birds per square mile at altitudes of 1,500-2,000 feet. At higher altitudes (2,000-2,500 feet) the population density is lower, perhaps as low as 40 per square mile. In the opened brush (1,500-2,000 feet) late summer populations of 250 per square mile have been observed. Opening the brush definitely encourages valley quail.

Mountain Quail. In heavy brush and in wildfire burns the mountain quail population density in late summer appears to be between 50 and 80 birds per square mile at altitudes of 1,500-2,000 feet. At 2,000-2,500 feet the late summer density is higher, perhaps 160 birds per square mile. In the opened brush at altitudes of 1,500-2,000 feet as many as 140 to 150 birds per square mile have been observed in late summer. While these findings seem to indicate that opening the brush encourages mountain quail, the secretive habits of these birds may lead to error. It is possible that the apparent higher densities in open brush are due to the better visibility there. This is supported by the opinion of Mr. Keithly, who believes that during the decade that he has been opening his brush the mountain quail population has not increased at all, even under complete protection.

California Jackrabbit. In the heavy brush the density is very low, about one jackrabbit per square mile. In the wildfire burns it is from 5 to 10 per square mile. In the opened brush the jackrabbits reached the greatest density found, fluctuating between 10 and 45 per square mile. The highest counts were made in summer.

Brush Rabbit. Brush rabbits are numerous in the heavy brush and in and around islands of heavy brush in wildfire or opened brush areas.

Mourning Dove. Dove populations in the heavy brush are low. They are higher in the wildfire burns and highest in the opened brush. This refers to breeding density.

It seems evident that the generous amounts of herbaceous vegetation, along with the edge-effect supplied by the scattered clumps of brush encourage the build-up of most resident small game species (cf. Burcham, 1950). In the opened brush are found not only the densest populations of most small game, but also cover which is most suitable for upland hunting. Even species such as the brush rabbit and mountain quail, which seem to be more numerous in the heavy brush than in the opened brush, may be hunted more successfully in the latter areas. It is almost impossible to hunt small game in heavy brush, especially after the first fall rains.

STUDIES ON METHODS OF OPENING CHAMISE BRUSHLANDS

Based on the foregoing results it would seem that the general objective in management of chamise brushlands for game should be to reduce the brush cover in spots, introduce herbaceous species where needed, and keep the browse plants in a productive condition. Opening dense chamise brushland provides a desirable interspersion of food and cover. If herbaceous species that are naturally or artifically seeded become abundant

in opened brushlands they help to stabilize the soil and markedly improve the forage for game animals. When grazed properly the good browse plants can be maintained in a productive condition over a long period of time. Once chamise brushlands are properly opened and the growth of herbaceous species is encouraged, good management should keep them productive with a minimum of further disturbance.

Methods studied in opening chamise brushlands are burning and grazing, mechanical means, and chemical treatment. Seeding of desirable forage plants should generally be combined with any of these methods to increase chances of establishment of a suitable cover of herbaceous species soon after the brush is removed. Most of the chamise brushlands opened thus far have been by a combination of burning and grazing. Although grazing is of little importance by itself, it can be a powerful tool for controlling chamise brush when used in combination with burning or mechanical means.

Burning and Grazing

Season of Burning

From the standpoint of game management, either spring or late fall burning has proven satisfactory in opening chamise. Spring burning, before the grasses outside of the brush areas become dry, has been relatively easy with reasonably good success in fire control. Any time that the humidity is around 25 to 30 percent and the wind is calm it is usually possible to light a fire at the bottom of a slope with the result that it will burn uphill (Figure 6). Usually the fire will not spread to the sides and will go out at the top of the slope. Areas of decadent brush, containing considerable dead material, will burn easiest and here firing should be started when the humidity is relatively high. Late fall burning is slightly more hazardous than spring burning. Usually more elaborate preparations are needed for fall burning than for spring burning. Information on techniques in burning may be obtained by reading *Use of Fire in Land Clearing* by Arnold, *et al.* (1951). Flame throwers are effective in setting fire in spring and late fall burning. The best way to learn about the use of fire is through experience in the field. The inexperienced should start under the instruction of someone competent in the proper use of fire. Manipulating brush by fire is not easy. It requires considerable planning, care, effort, and patience to do a good job.

Summer burning in chamise brushlands for game is not recommended because of the difficulty and expense in fire control.

Studies have not yet gone far enough to determine precisely whether most of the burning for game in chamise brush should be in the spring or late fall, or whether a combination of the two seasons of burning should be used. After spring burning, sprouts will appear within 3 or 4 weeks and supply a highly nutritious forage for deer during the dry summer months. However, studies thus far indicate that few brush seedlings appear on spring burns. This would mean that sprouting species, such as chamise, are favored over nonsprouters, such as wedgeleaf ceanothus. If this is borne out by further studies on burns made before seed maturity, the composition of the brush cover for deer may be adversely affected by spring burning. Some fall burning may be necessary then to provide

FIGURE 6. Controlled "spot" burning in May in chamise. The fire was lit at the base of the slope with the result that it burned uphill. It did not spread to the sides and went out at the top of the slope. The burning was done on a clear day when the humidity was about 27 percent. Grasses outside of the brush area were still green.

young plants of wavyleaf ceanothus, wedgeleaf ceanothus, and other valuable nonsprouting browse plants. Further studies are needed on this phase of brushland management.

Control of Sprouts

Control of sprouts after burning is an essential step in the opening of dense chamise brushlands. Both measurements and observations indicate that deer will probably be one of the most effective tools for this purpose in suppressing sprouts through browsing. Sheep can also be used in some places to good advantage, especially in large burns where the deer population is inadequate to suppress the browse plants. Without utilization, chamise sprouts will attain an average height of nearly 20 inches the first summer after fall burning, interior live oak 30 to 40 inches (Figure 7). Thus, unless the sprouts are browsed they soon become so large as to be more or less useless as food for game. Deer and sheep are effective in controlling sprouts by suppressing height growth and by killing some of the plants the first season following burning (Figures 8, 9, 10). Failures in brush control and reseeding in chamise brushlands occur often due to lack of sprout control. The sprouts must be suppressed if brush control and reseeding are to be successful in such brushlands. Not enough attention has been given to this phase of management.

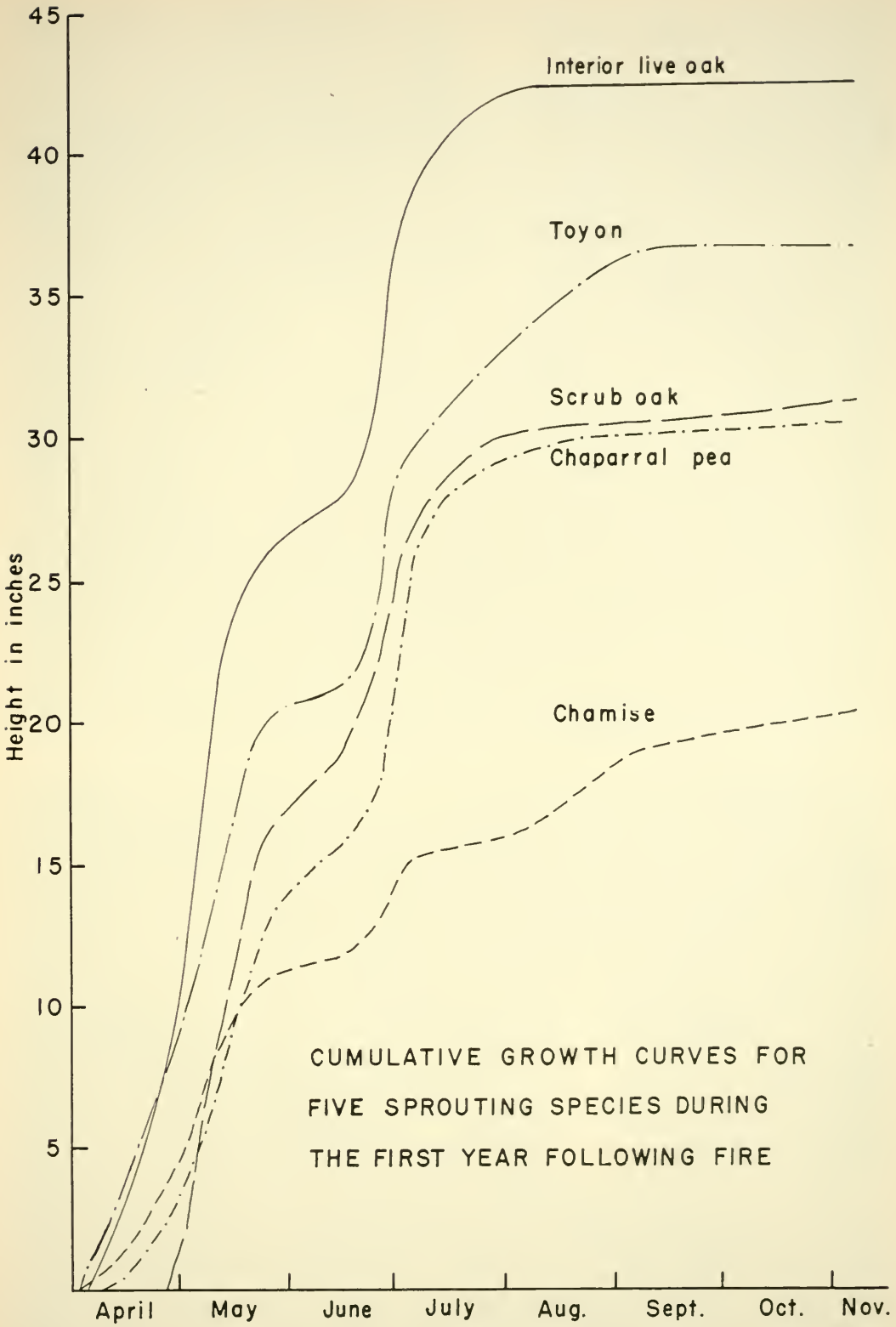

FIGURE 7. Sprout growth control is an essential step in opening chamise brushlands. Without utilization the sprouts grow rapidly, soon become unpalatable and of little use as food to deer. Curves represent growth in one year of several important browse species in the absence of grazing.

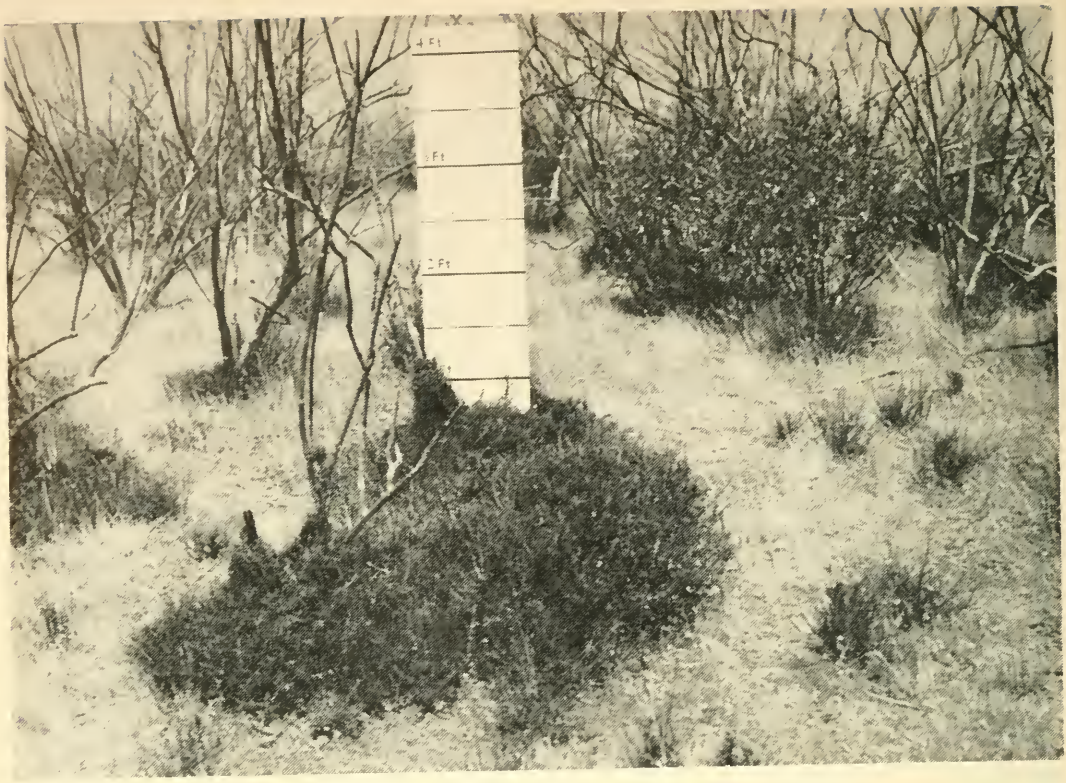

FIGURE 8. On this south-facing slope, burned in 1945, a large population of deer has kept the sprouts (large plants) and seedlings (small plants) browsed down and in productive condition. The deer also made good use of the grass. Photo taken in 1951.

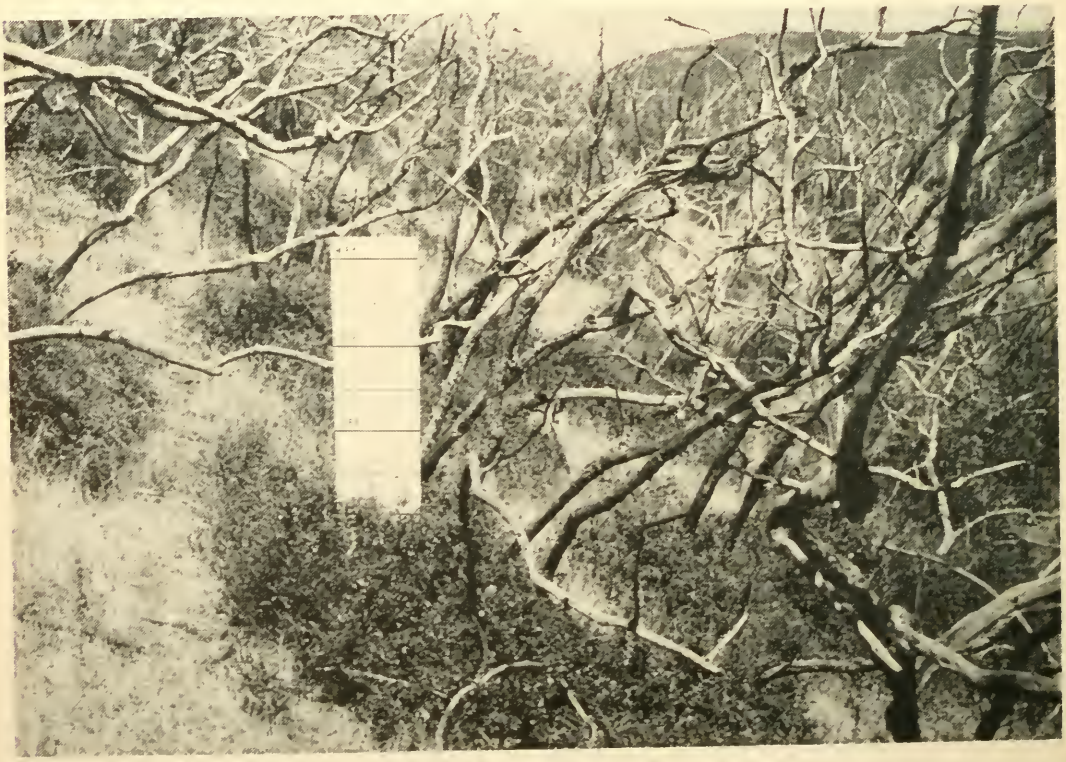

FIGURE 9. This north-facing exposure of mixed chaparral was burned in 1945. Heavy browsing by deer has kept the brush low and productive. Photo taken in summer, 1951.

FIGURE 10. Very heavy browsing by deer the first year after burning killed most of the sprouts, but seedlings survived and will continue to furnish browse. Grassy spots in brush furnish valuable forage for deer in late winter and early spring when the herbage is green and succulent.

The extent to which deer and sheep may suppress sprout growth is indicated by measurements of chamise sprouts under various conditions of grazing use and in protected areas on two-year-old burns (Figure 11). Even light browsing by deer considerably suppresses the growth of sprouts. A majority of the sprouts browsed lightly by deer averaged about 18 inches in height while those protected by fenced exclosures averaged between 22 and 32 inches.

Heavy utilization from year to year will continue to suppress sprout growth (Figure 12). A majority of plants browsed heavily for five years averaged only 17 inches in height while plants protected from browsing averaged between 22 and 32 inches in only two years. Sprouts protected entirely from browsing for five years were not available for comparison.

Close utilization by deer may kill many of the sprouts the first year following fire. This results in opening the brush. Some sprouts may be killed the second year, but few, if any, are killed after the sprouts are five years or more old. After the chamise plants are six to eight inches tall the stiff stems prevent the deer from grazing so close as to kill the plants. On a seven-year-old burn no plants of chamise were killed by heavy browsing in the past two years.

In August, 1948, about 25 acres of old brush burned along with some 300 acres that had burned in 1945. This area supported an estimated 100

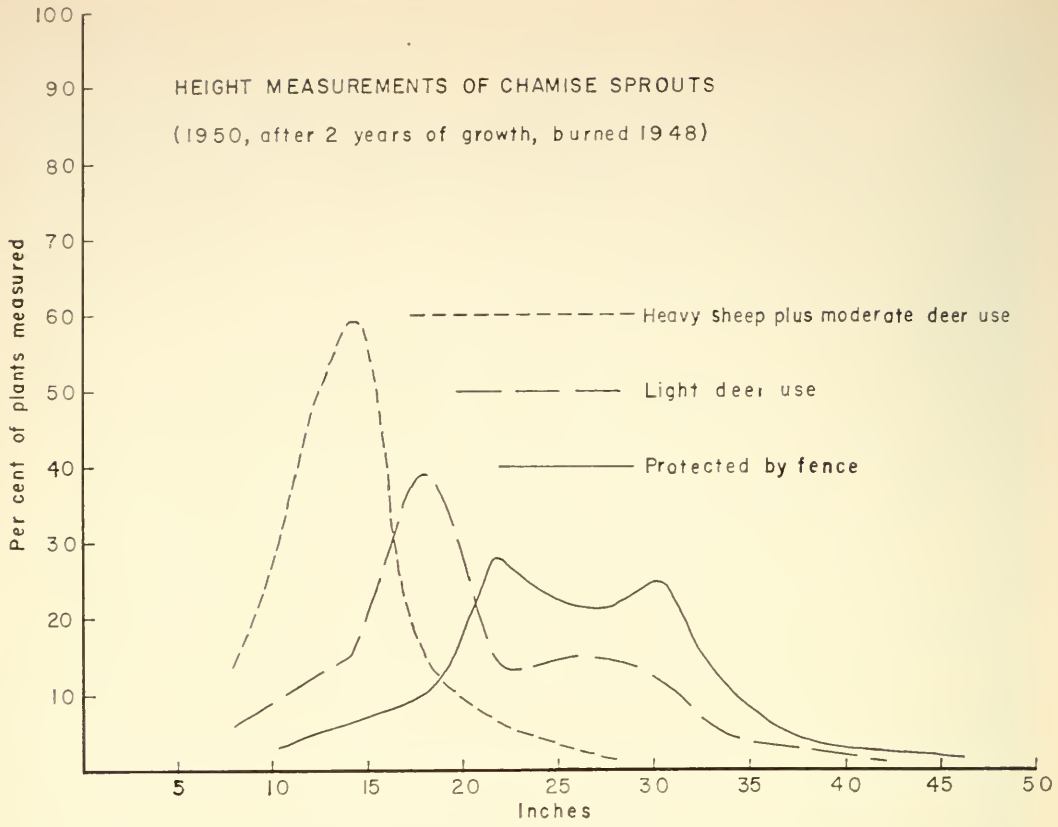

FIGURE 11. Curves showing the effect of browsing in retarding sprout growth. Most of the plants heavily browsed by sheep plus deer measured 14 inches while most of those protected from deer and sheep average between 22 and 32 inches. Light use by deer also considerably retarded height growth of sprouts.

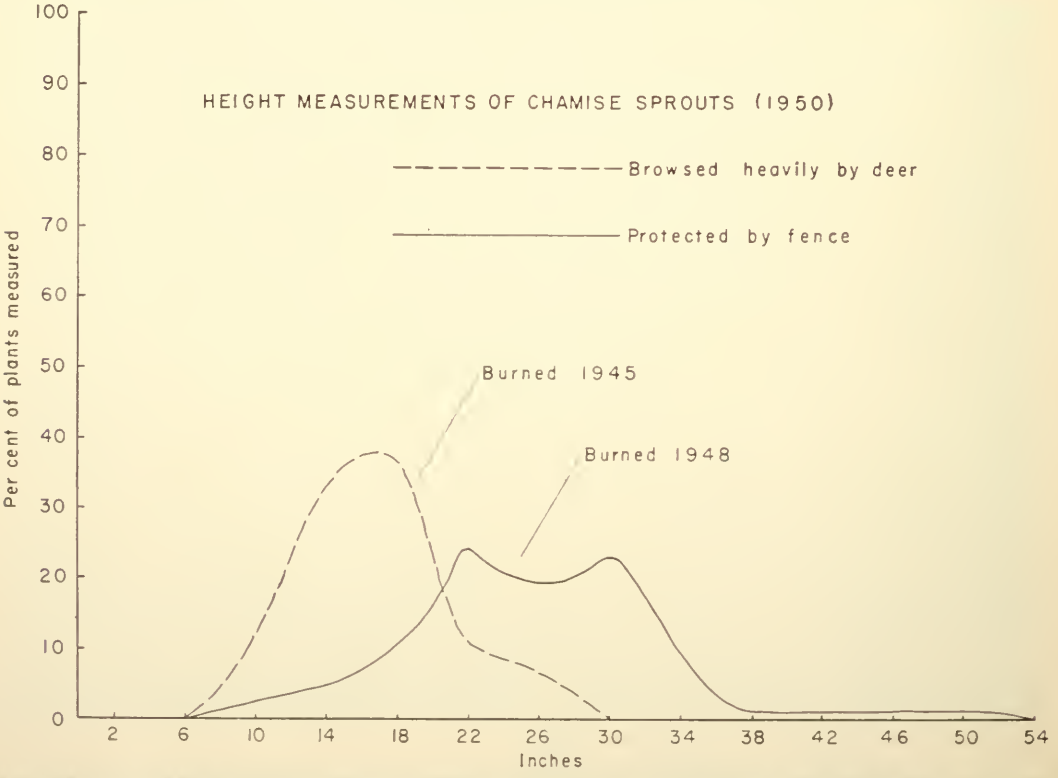

FIGURE 12. This graph indicates the effect of heavy deer browsing in retarding sprout growth. The sprouts browsed closely by deer averaged about 17 inches in height after five years while most of those protected from deer and sheep were between 22 and 32 inches in only two years.

or more mature deer per square mile. On the 25 acres of new burn, close browsing by the large deer population took place as soon as sprouting began. As no additional burns had been made here since 1948, sampling in 1950 furnished a measure of the effectiveness of two seasons of heavy deer browsing in opening dense chamise. Both northwest and southeast exposures were represented in the 25-acre area; these were sampled separately to determine the correlation between composition of the plant cover and the effect of deer browsing on brush recovery. The northwest exposure had chamise mixed with toyon, Eastwood manzanita, scrub oak, and poison oak; the southeast exposure was principally chamise with some wedgeleaf ceanothus.

Figures were obtained on number of brush plants alive, number killed by fire, number killed by browsing, and the average height of the brush sprouts from browsed and unbrowsed plants (Table 3).

TABLE 3

The Results of Close Browsing by Deer Following Fire. The Effect of Close Deer Browsing Was to Open the Dense Stand of Brush by Killing Many of the Sprouts

Exposure	Species	Number of plots	Plants alive (percent)	Plants killed		Average height of sprouts	
				By fire (percent)	By grazing (percent)	Browsed (inches)	Unbrowsed (inches)
NW	Chamise	24	19.7	26.0	54.3	4.8	20.1
	Eastwood manzanita	12	50.0	25.0	25.0	6.8	23.0
	Toyon	9	88.4	0.0	11.6	7.7	36.8
	Scrub oak	3	100.0	0.0	0.0	4.0	32.1
SE	Chamise	30	30.7	31.9	37.4	4.8	20.1
	Toyon	3	100.0	0.0	0.0	7.3	36.8

On the northwest exposure over one-half of the sprouting chamise plants were killed by deer browsing. It is significant that 25 percent of the Eastwood manzanita plants were also killed by browsing for these sprouts are usually eaten only lightly by deer. Among the sprouting species, scrub oak seemed most resistant to the effects of heavy browsing even though the sprouts on it were eaten to a lower average height than on any of the other species. Observations indicated that the weakened plants usually died in winter following heavy browsing in summer.

On the southeast exposure fewer sprouted plants were killed by deer browsing than on the northwest exposure, probably because of lighter use there in the winter and early spring months. In both areas, however, the effect of close deer browsing was to open the dense stand of brush by killing many of the sprouts.

It was found also that close grazing by sheep in addition to light deer use is an effective way of opening areas of dense chamise brush following fire. Results of sampling on an area browsed heavily by sheep in addition to light use by deer are summarized in Table 4.

TABLE 4

Results of Light Utilization by Deer Compared to Heavy Utilization by Sheep Plus Deer in Opening Chamise Brush Following Fire

Date of sampling	Number of plots (mil-acre)	Mature chamise plants killed	
		By fire (percent)	By grazing (percent)
Area utilized lightly by deer only			
7/20/48	64	25.0	
12/21/48	45		0.7
6/29/49	45		0.0
Area used heavily by sheep from March to July 10, 1948, and lightly by deer			
7/21/48	40	27.0	
12/21/48	50		22.0
6/14/49	45		42.0

In both areas approximately one-fourth of the mature plants were killed by fairly intense fire, which is about normal as indicated by sampling in many places. In the area where deer utilization was light, less than 1 percent of the plants died the first year after the fire and none in the second year. However, in the other area, heavy use from a combination of sheep and deer killed 64 percent of the plants in addition to the 27 percent killed by the fire. Opening to this extent might not always be desirable. But in suitable places where burned areas are so large that deer cannot effectively suppress sprout growth, sheep can be used to good advantage in opening the brush and prolonging use by deer.

Size and Amount of Area to Burn

Burned spots should usually be small, 5 to 10 acres or so in size, in order to form as much edge as possible. The acreage to be burned should be decided before burning is started. If the deer population is dense or if a band of sheep is available to control sprout growth the first year, the acreage burned may be fairly large. In general, however, deer populations in heavy brush areas are fairly low and the burns should be kept small. Spot burns of about five acres scattered here and there are probably sufficient for initiating a program of managing chamise brushlands. The spots should be scattered evenly over the whole area rather than clumped. It is wise to proceed in stages, so that the deer can keep on top of the brush sprouts. In the second or third year it might be desirable to make new burns in the region where deer use has been heavy. If the deer are effectively opening the brush, it might be well to go rather fast; but if not, it would be desirable to proceed slowly. This procedure should continue until the desired amount of opening has been accomplished.

Mechanical Control of Brush

In suitable areas chamise brushlands may be opened by mechanical means such as heavy disking or by pushing the brush over with a bulldozer, holding the blade about six inches above the soil (Figure 13).

FIGURE 13. Chamise brush pushed over with bulldozer blade about six inches above the soil. The plants that are not totally destroyed grow sprouts and furnish abundant browse for deer.

FIGURE 14. Pattern of opened brush obtained by using heavy disk. The grassy areas were disked, the brush strips were not. This work was done by the U. S. Forest Service on the Mendocino National Forest. Photo taken May 28, 1951.

Pushed-over brush need not be burned. There are several advantages in mechanically opening chamise brushlands. In the first place, a residue is left on the soil which is helpful in erosion control. The residue also gives reseeded grasses protection against frost heaving and intense heat and drying from the sun. If pushing over brush along ridge tops enables one to start herbaceous vegetation more easily than otherwise, the practice may provide an added seed source for revegetation when slopes below are burned. This is an important point, for seeding failures are common in burned chamise brushlands and any insurance of a continuing seed supply is invaluable. There is evidence that a more favorable composition of brush cover for deer can be maintained by mechanical means than by using fire. Mechanical means can be used in areas where it is too dangerous to attempt burning. Another advantage in mechanical control is that patterns of interspersion of brush and grass can be obtained without difficulty (Figure 14).

The chief disadvantages of mechanical removal are that the cost may be greater than strip burning in the spring, and that many areas are relatively inaccessible to mechanical equipment. Pushed-over brush creates quite a fire hazard because much of the brush is killed. On the other hand, heavy disking tends to incorporate the residue in the soil and the fire hazard is not high from this practice. The U. S. Forest Service has pioneered in the use of the heavy disk in chamise brushlands.

Chemical Control of Brush

Studies on the use of hormone sprays in opening brush for game were limited to treatment of seedlings and sprouts following burning and grazing. The effectiveness of the method seems to be correlated with the vigor of plants which, in turn, is affected by grass competition and intensity of grazing. In view of the expense of hormone sprays, other methods of opening the brush for game appear more practical at this time. Further studies are needed to determine how chemicals can be used to control composition of the stand to reduce the nondesirable species and favor the more desirable ones.

RESEEDING OF CHAMISE BRUSHLANDS

Where chamise brush has been removed, it is desirable to reseed to suitable forage species in order to establish a plant cover as quickly as possible.

Three years of study on reseeding of such brushlands in Lake County have indicated the importance of several factors affecting successful revegetation. These are: species used, dates and rates of reseeding, frost heaving, grazing preference by game animals, and competitive relationship between reseeded grasses and brush plants.

Species Used

Several annual and perennial species were used in the reseeding trials. Annuals included soft chess, red brome, domestic ryegrass, rose clover and bur clover; perennials included hardinggrass, orchardgrass, perennial ryegrass, smilo, tall fescue, burnet, and sweet clover.

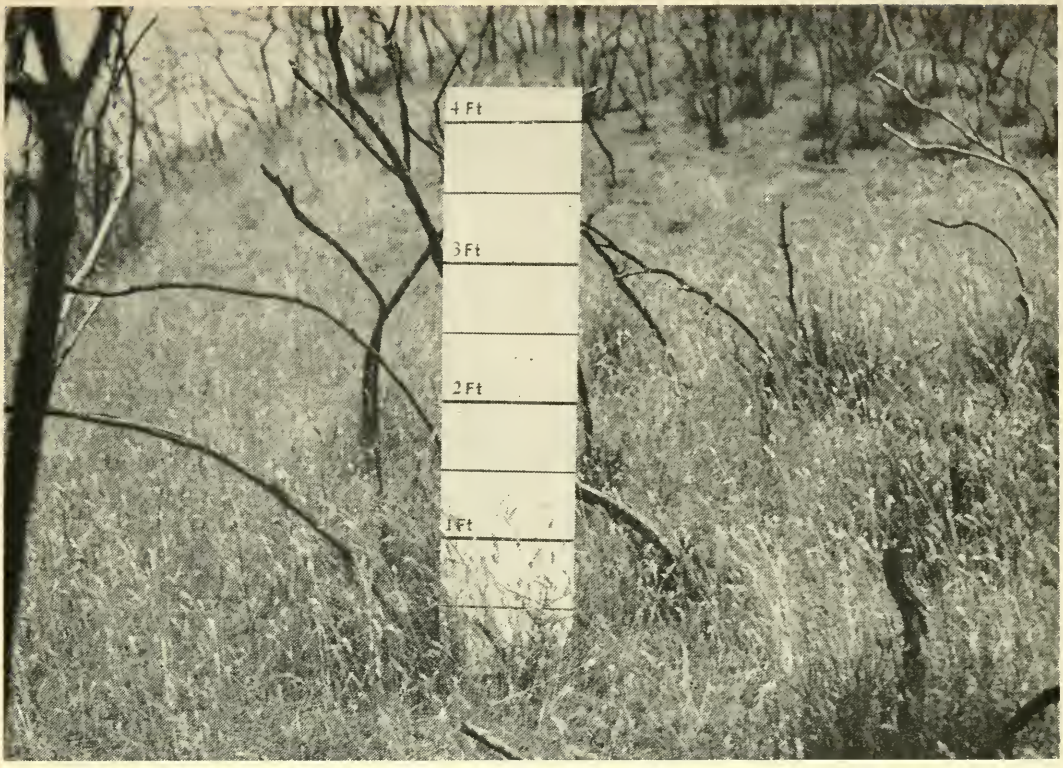

FIGURE 15. Area of chamise brush reseeded to soft chess after controlled burning. This species is well adapted to reseeding of poor chamise brushlands. It is well liked by deer in spring when green but is not liked after it is dry. Photo taken in July after the grass was dry.

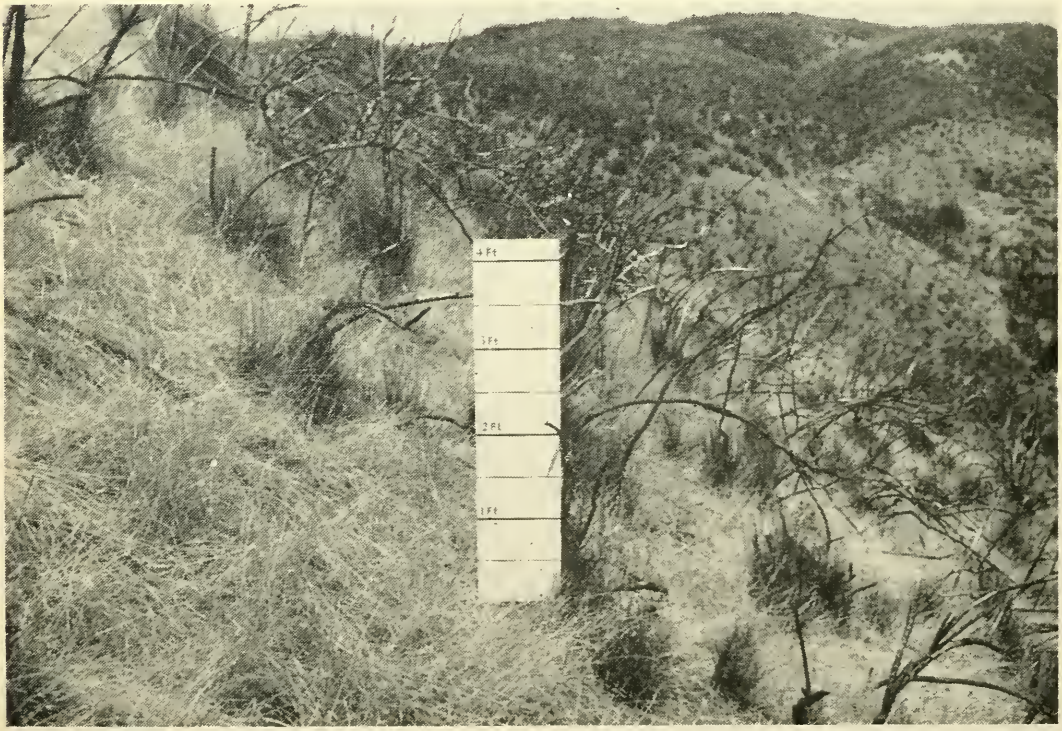

FIGURE 16. Area of chamise brushland reseeded to domestic rye-grass following controlled burning. This grass has done moderately well on chamise brushlands. Photo taken in July after the grass was dry.

Over a period of three years, which included both good and poor climatic conditions for establishment of herbaceous vegetation, soft chess proved to be the most satisfactory of the annuals (Figure 15). Although seed of this species is not easily available at present it can be recommended for reseeding of relatively poor chamise brushlands. Red brome did as well as soft chess but is inferior as a forage plant. Domestic ryegrass did fairly well in most instances when planted before the start of fall rains (Figure 16). Rose clover appears to be a promising legume for reseeding chamise brushlands (Love and Jones, 1952). It is a new introduction and was tested in these studies only one year. Bur clover did not give satisfactory results.

Perennials generally did better at about 2,400 feet elevation than they did at about 1,500 feet. At the lower elevation, annuals were generally more satisfactory. Perennials that did fairly well include hardinggrass, orchardgrass, smilo, burnet and tall fescue.

Date and Rate of Reseeding

In general, seedings made about the middle or latter part of September shortly before the start of fall rains, have been the most successful. Seedings made in the spring or summer after spring burns have not been as successful as those made in late summer or early fall. December plantings did fairly well but did not make as much growth as the early fall seedings. Seedings made in February were complete failures.

Results with rates of reseeding varied somewhat with weather conditions. In favorable years fewer pounds of seed were needed for a satisfactory stand than in poor years, perhaps due to better germination. About two pounds of soft chess per acre appeared to be nearly as satisfactory as four pounds. Stands of domestic ryegrass improved regularly with increase in the seeding rate up to 10 pounds per acre. Hardinggrass and tall fescue gave satisfactory germination with four pounds per acre. Smilo, a small-seeded species, required two pounds. However, the heavier seedings of all species produced stands more effective in competing with brush seedlings.

Frost Heaving

Frost heaving was the most adverse factor affecting the establishment of reseeded species in burned chamise brushlands in Lake County, especially at elevations around 1,500 to 2,400 feet. In each of three seasons of study, 1948 to 1951, frost heaving has been appreciable. In the winter of 1948-1949 severe cold in December heaved out 99 percent of the newly germinated seedlings of domestic ryegrass, hardinggrass and orchardgrass. In 1949-1950 approximately 80 percent of the seedlings of several species on north exposures were heaved out, and about 15 percent of those on south exposures. In the winter of 1950-1951, which was mild, about 35 percent of the smilo seedlings on a southeast exposure were lost and about 65 percent of those on a northwest slope. Hardinggrass and annual species, however, were not so adversely affected in 1950-51. From observations of excavated root systems those species with many fine roots, such as smilo, were more susceptible to frost heaving

than those with fewer, coarser ones, such as hardinggrass. Once domestic ryegrass roots penetrate below the frost line there is little danger from heaving. In the winter of 1950-1951 the annual species, especially resident ones, were not noticeably damaged by the action of frosts. This is one reason why resident annuals have done better in seeding chamise brushlands in this area than many of the introduced species. Frost heaving appeared to be more severe around 1,500 to 2,400 feet than higher where there was less daily freezing and thawing. Also, frost heaving was more severe in loose soils than in those tending to have a tight structure.

Preference by Grazing Animals

Deer make their greatest use of reseeded grasses in the early spring before brush sprouts become available on newly burned areas. In studies of comparative grazing use in the spring, domestic ryegrass and soft chess were heavily grazed by deer while hardinggrass and smilo were only lightly used. After the annuals are dry, the hardinggrass and smilo are heavily used. All of the grasses seeded have been grazed to some extent and are an important source of feed on burned areas. In some instances deer did damage to newly seeded stands by close grazing and trampling. Damage was greatest in small plots where less than 10 acres were seeded and the concentration of deer was high. In large seedings or a number of small ones, deer were responsible for little or no damage. Moderate grazing of domestic ryegrass and soft chess by deer might be helpful in causing the grasses to tiller and increase in density.

California jackrabbits made much use of reseeded species. They were next to frost heaving in causing damage. All of the perennial species and also domestic ryegrass were heavily used. The latter was heavily grazed after it was dry, but soft chess nearby was little used. In areas where there is no ryegrass, stomach analyses show that soft chess seeds are readily taken during the summer. Perennial species were heavily used by jackrabbits during summer and severely damaged in many cases.

Competition Between Reseeded Species and Brush Seedlings

The importance of a good stand of grass in suppressing the growth and establishment of brush seedlings was noted soon after the studies were started in 1948. Sampling over a three-year period shows a very high negative correlation between the density of herbaceous cover and number of brush seedlings on seeded chamise brushlands in Lake County (Figure 17). In very dense stands of domestic ryegrass, few brush seedlings emerged and none survived. Brush seedlings appeared in thin stands of domestic ryegrass and in perennial stands but many of these died during the summer. The close relation between density of herbaceous cover and number of brush seedlings increases the need for a fairly dense cover of grasses the first year after burning. Dense stands of domestic ryegrass had only little retarding effect on the sprouts from chamise root crowns. Some grasses offer more competition than others; for example, domestic ryegrass is stronger than the perennials (Schultz and Biswell, 1952).

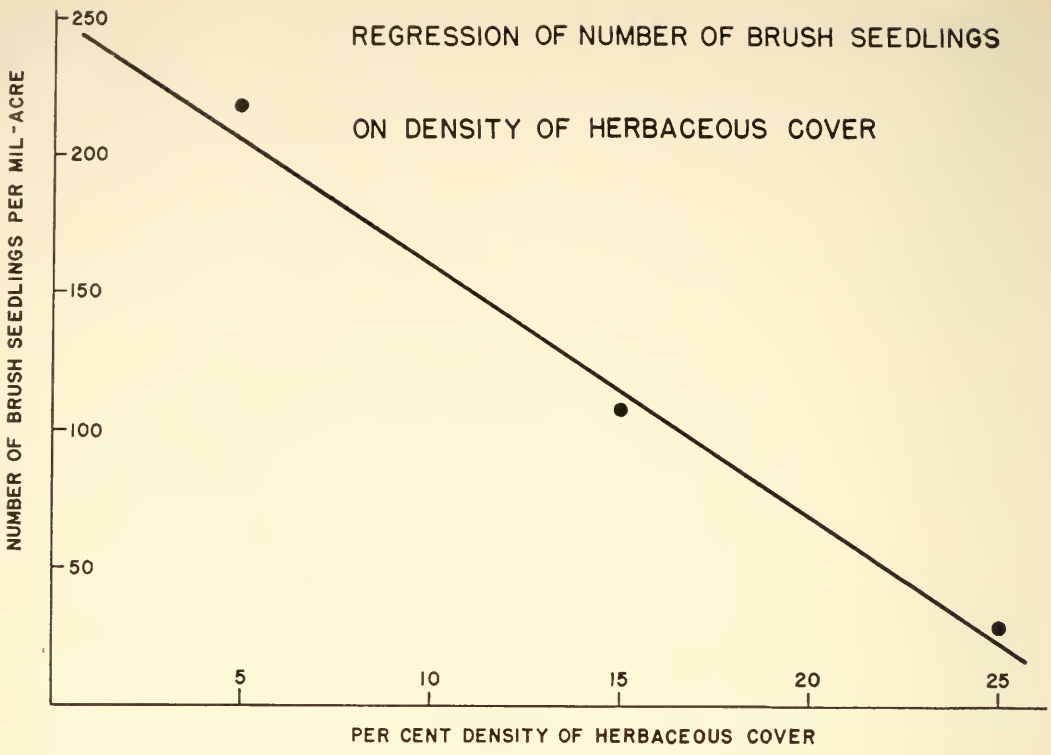

FIGURE 17. The line shows the negative correlation between number of brush seedlings and density of herbaceous cover. The plotted points are based on figures from four replications for each density class. As the grass density increased the number of brush seedlings decreased. The measurements were made late in the summer. The close relationship between grass density and brush seedlings increases the need for a fairly dense cover of grasses the first year in opening chamise brush.

STEPS IN OPENING CHAMISE BRUSHLAND

Several steps in the operation of opening chamise brushland are now well understood on the basis of experiments and are outlined below. It is logical to assume that the more nearly the areas in question resemble the general area studied in Lake County, the more closely these steps will apply. Knowledge of both the game population and the plant population in the brush area to be manipulated and managed is essential.

1. *Location of Deer and Their Approximate Density.* The success of opening chamise brushlands is dependent upon the presence of at least a few deer in the general locality. There is small possibility of luring deer long distances to areas of low concentration simply by opening the brush. A total absence of deer may indicate a lack of water or some other limiting factor; in this case opening of the brush may be of little or no benefit.

Information about the number of deer and their location may be gained accurately enough by reconnaissance through the area, or by noting kill of bucks during past hunting seasons, or by testimony of local residents and sportsmen.

2. *Selection of Areas.* Chamise brushlands vary widely in such features as soils and topography. Some are better adapted to growing grasses than others. In beginning a program of managing brush, the more productive areas should be selected first, areas where there is reasonable

assurance that grasses will grow abundantly. Usually this can be determined by observation of abundance of grasses in such places as wildfire burns and in clearings along power lines. Soil examination and surveys should prove helpful, and luxuriance of the brush often indicates the quality of the site. Scattered grasses in brush are a good indication that they will increase if the brush is opened and competition decreased.

3. *Methods of Opening the Area.* Whether fire or mechanical means are used in opening the brush depends largely on the risk of using fire, brush cover conditions, and type of terrain (Figure 18). Where the

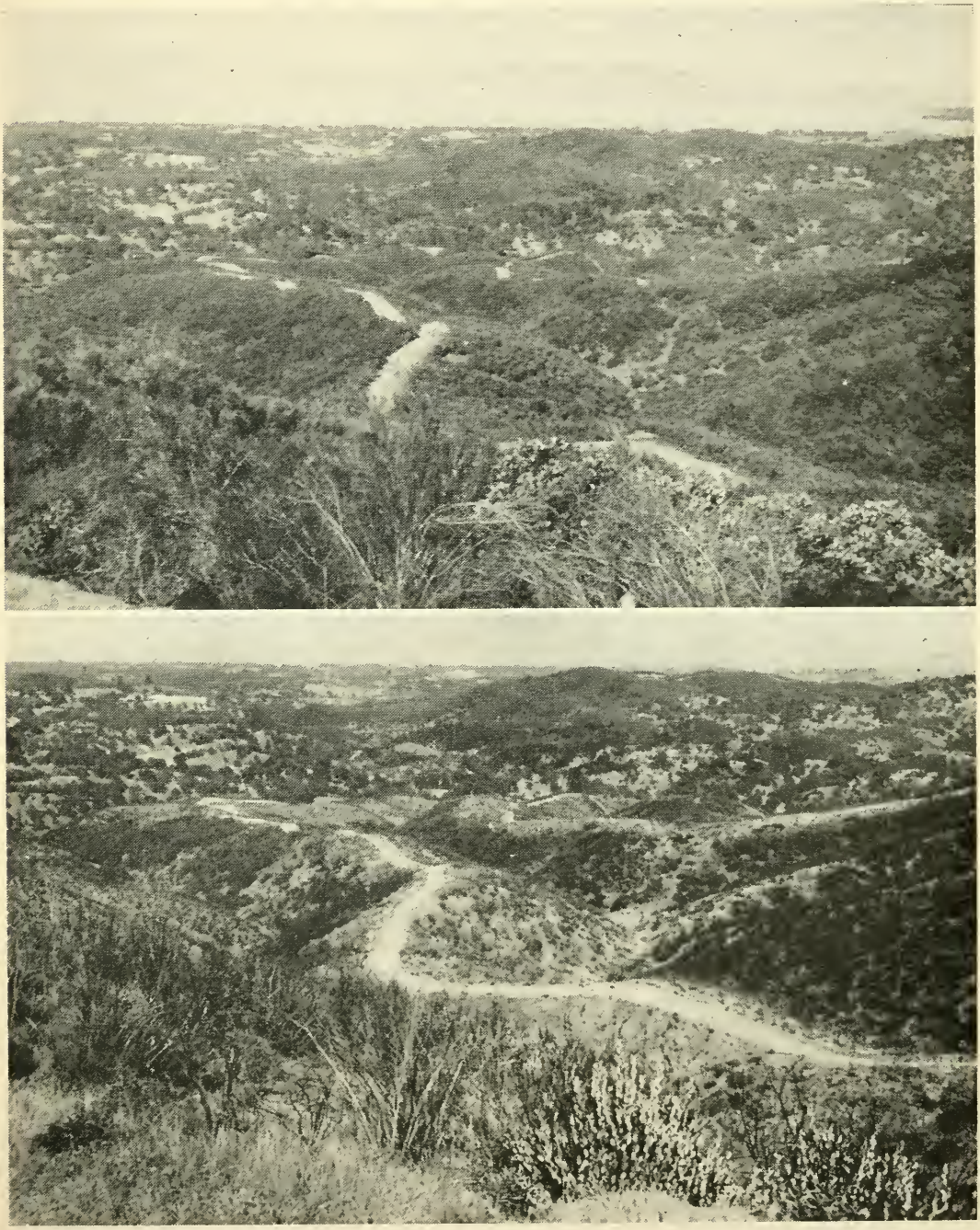

FIGURE 18. Views of an area in Lake County before and after the chamise brushland was opened by controlled burning and reseeding. Upper photo taken in 1949; lower, 1951.

vegetation is predominantly chamise on south exposures and mixed chaparral on north exposures, spring burning may be done without very high risk. The south-facing chamise slopes can be burned on days of relatively low humidity and with proper wind velocity and direction, from February through May, for then the north-facing slopes of mixed chaparral are not very likely to burn. On quiet days, fires lit at the bottom of the chamise slopes usually go out at the ridge top and ordinarily no more area will be burned than the length of the slope by the distance fired along the bottom. One or two men equipped with flame throwers can usually do the burning. Throughout the period from February through May, there will be many days when it is too moist to burn and others when it is too dry to use fire safely.

Where chamise brush occupies all exposures, and is of uniform density, the risk of using fire is greater than where the type of brush varies with exposure. With a uniform brush cover, the fire is more likely to spread because conditions for burning are more uniform also. Where grass borders the brush, burning when the grass is green adds an element of control. However, it may be dangerous to burn at any time when the wind is high and the humidity below 25 percent. One should be familiar with the state fire laws and obtain a fire permit from the local forest ranger during the fire season.

Where conditions for burning are too hazardous, and the terrain is not too steep, mechanical means may be used to open the brush.

4. *Extent to Which Area Should Be Opened.* The extent to which a brush area should be opened depends almost entirely on the deer population present. Where a square mile has less than 10 deer, a half dozen scattered, opened areas, each of about five acres may be sufficient. Where the deer population is greater than 10 per square mile, a correspondingly larger number of areas should be opened. If the new sprouts are browsed so heavily that a majority of them are killed the first season then a larger number of spots should be opened the next year. On the other hand, if browsing is light, it is desirable to wait two or three years before additional spots are opened. Approximately 30 percent of the area should be left in well distributed dense brush as cover for game. In a few years the deer population will build up to the carrying capacity of the range. When this point is reached it will be necessary to control the deer population to maintain this balance.

5. *Reseeding to Adapted Forage Species.* All areas cleared of brush should be reseeded to adapted forage plants before the first fall rains. If the reseeding is not done by this time, however, it is still not too late to seed soon after the first rains, but with less satisfactory results. Insofar as possible species valuable for forage and watershed cover should be used. These are not known for all cases and will vary with locality; some testing should be done in all areas.

6. *Reburning.* Where too much area is covered in the initial burn for deer to suppress sprout growth, it may be necessary to reburn in spots to retard sprouts. This should be done two to four years after the first burn, where reseeded grasses will carry the fire. In general, however, as little reburning as possible should be done for this tends to eliminate certain of the valuable nonsprouting species, and may also result in

opening the brush too much. Insofar as possible, sprout growth should be retarded by deer browsing and areas maintained in open condition this way. When areas are properly opened every care should be taken to avoid wildfires for these are likely to upset the proper interspersion of brush and herbaceous plants and may not leave enough dense brush cover for deer. After an area is opened and the proper balance between dense brush and opened area is attained, it may prove more desirable, where feasible, to maintain this condition by mechanical means than by fire.

7. *Grazing Management.* Attention should be given to grazing management, especially where animals other than deer use the range. The general objective should be to leave enough grass residue on the ground for an effective watershed cover, and to maintain a high level of fawn production without depletion of range carrying capacity. Where the browse species are properly utilized the grasses are likely to be properly grazed, too (Figure 19). Areas fully stocked with deer will scarcely support any cattle or horses because the additional animals would result in too close grazing. Utilization by sheep is quite similar to that by deer; where both kinds of animals use the range, proper allowance must be made for each. In some cases, jackrabbits may become sufficiently abundant to justify reducing their number.

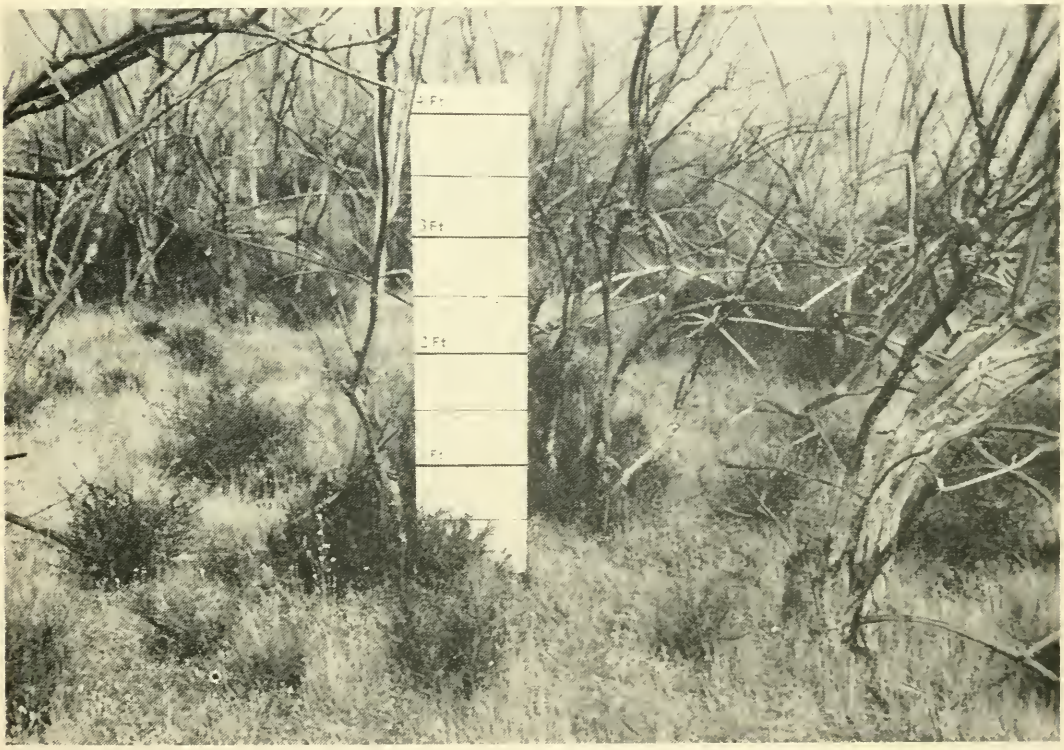

FIGURE 19. View of area burned in 1945 and used only by deer for six years. Both the browse and grass show about proper utilization. Photo was taken September 13, 1951, near the end of the dry forage period. If used also by other kinds of animals adjustments should be made for proper utilization of the grass, always leaving enough for an effective watershed cover.

SUMMARY

1. Studies on the management of chamise brushlands for game were made in Lake County, California, from 1948 to 1951. Brushlands on the study areas comprise two types: those in which chamise predominates on south exposures and those where broad-sclerophyll shrubs and trees predominate on north-facing exposures. The dominant shrubs and trees are chamise, interior live oak, Eastwood manzanita, scrub oak, California laurel, toyon, wedgeleaf ceanothus, wavyleaf ceanothus, deerbrush, Stanford manzanita, yerba santa, poison oak, birchleaf mahogany and chaparral pea, approximately in that order of abundance.
2. Chamise occurs on a variety of soils in this area. The Maymen series is the most extensive. These soils are less than 12 inches deep. The more productive soils belong to the Dorado, Los Gatos, and Laughlin series. Chamise-covered soils are generally low in nitrogen even where the woody vegetation has not been disturbed over a long period of time.
3. Chamise brushlands have been generally looked upon as valuable for game and watersheds. However, little has been done to manage them for either except to attempt total fire exclusion. This has not been entirely successful since wildfires occur frequently; some are very large and destructive.
4. The primary purpose of this study was to determine whether game populations will build up under brushland management, and, if so, the most satisfactory way of managing chamise brushlands for game production.
5. Black-tailed deer populations were studied under three different conditions of chamise brushland: (1) Heavy brush cover, protected from fire; (2) Wildfire burn; (3) Opened brush, consisting of an interspersion of grass with patches of dense brush. Observations and less detailed studies were made of the valley quail, California jackrabbit, brush rabbit, mountain quail, and mourning dove.
   a. Number of deer in the heavy brush averaged 10 to 30 to the square mile; in the wildfire burn 5 to 160; and in the opened brush about 40 to 110. Populations in the heavy brush and opened brush were rather stable; but in the wildfire burn large numbers of deer moved in when the sprouts were young and tender and out during cold weather.
   b. In adult does the ovulation rates were: Heavy brush 84 percent; wildfire burn 116 percent; opened brush 147 percent. Ratios of fawns to 100 does following the rut were: Heavy brush about 60 to 85; wildfire burn 100 to 110; opened brush 115 to 140.
   c. Bucks from opened brush were heavier than those from heavy brush; this tendency was stronger in young deer than in medium-aged ones. Bucks from the wildfire burns tended to be as heavy as those from opened brush.
   d. Herbaceous plants when available and green are utilized heavily by deer. From February to May the deer in opened brush foraged largely on herbaceous plants, whereas those in the heavy brush foraged almost entirely on shrubs. In the wildfire burns herbaceous plants comprised about half of the forage in March and April.

e. Valley quail populations in late summer were about two and one-half times as great in opened brush as in heavy brush or in wildfire burns. Mountain quail were difficult to census but more were counted in opened brush than dense brush. Jackrabbits fluctuated from 10 to 45 per square mile in the opened brush but in heavy brush only about one was found per square mile. In wildfire burns they reached densities of 5 to 10 per square mile. Brush rabbits were numerous in the heavy brush. In wildfire burns and opened areas they existed largely in the remaining spots of heavy brush. Mourning doves were the most abundant in opened brush. They were found occasionally in wildfire burns but seldom in the heavy brush.

6. Methods studied in opening chamise brushlands to improve conditions for game were burning, grazing, mechanical means, and chemical treatment.
   a. Both spring and late fall burning proved satisfactory in opening chamise brush. Summer burning in chamise brushlands for game is not recommended because of difficulties and expense in fire control and the possibility that the area burned will be too large.
   b. Control of sprouts through browsing following initial brush removal is an essential step in the opening of dense chamise brushlands.
   c. Spot burns of about five acres evenly scattered are probably sufficient for initiating a program of managing chamise brushlands. Ultimately not more than 70 percent of a brush area should be treated and the remainder left in dense brush as cover for game.
   d. Some areas of chamise brushlands may be opened by mechanical means such as bulldozing or disking.
   e. Use of hormone sprays were limited to treatment of seedlings and sprouts. Other means of opening the brush for game appear more practical at this time.
7. Chamise lands should be seeded following brush removal to increase forage production, to lessen erosion, to offer competition to a potentially overdense stand of brush seedlings, and to furnish fuel for a reburn if necessary.
   a. The most promising species tested were soft chess, domestic ryegrass, hardinggrass, smilo, tall fescue, orchardgrass, rose clover and burnet. Seedings made shortly before the start of fall rains did best. However, those made shortly after the first rains have been successful. Most failures in reseeding were due to frost heaving and heavy use by jackrabbits.
   b. Deer make their greatest use of reseeded grasses in the early spring. At this season, soft chess and domestic ryegrass were more heavily grazed than others. But all reseeded species were used and can make up an important part of the deer diet.
   c. A negative correlation was found between density of reseeded grasses and survival of brush seedlings.
8. In opening new areas of chamise brushlands, steps to be considered are: Location of deer and their approximate density, selection of area, methods of opening the area, extent to which area should be opened, reseeding to adapted forage species, reburning, and grazing management.

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LIFE HISTORY OF THE BLUE ROCKFISH *SEBASTODES MYSTINUS*[1]

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INTRODUCTION

As a preliminary step toward a general survey of the rockfish of the genus *Sebastodes,* the writer undertook the problem of outlining the life history of *Sebastodes mystinus* Jordan and Gilbert, commonly called bluefish or blue rockcod. Although this species is not as important commercially as many others of the genus, it is easily available in sufficient numbers to permit an outline of its life history.

This study was carried out at the Hopkins Marine Station of Stanford University, Pacific Grove, California. Work began in the summer of 1929, at which time 280 fish were tagged. Nothing more was done until June, 1930, when tagging was resumed for a few months along with regular sampling, which was continued for an entire year.

When the investigation was started, no work had been carried out on the life histories of the fishes of the Monterey Bay region and there was little or no knowledge of the seasonal changes in the physicochemical conditions of the waters. As a consequence we had no ideas in regard to the difficulties inherent in the problem. As the work progressed and as

FIGURE 1. Blue rockfish from Monterey Bay, April 1, 1931. *Photograph by J. H. Wales and Wm. A. Dill, April, 1931.*

[1] Submitted for publication May, 1952. Modified from a typewritten thesis submitted to Stanford University, June, 1932, in partial fulfillment of the requirements for the degree of Master of Arts. The common name "blue rockfish" replaces the department's old official name of "priestfish." It is believed that the new name more nearly conforms with popular usage.

the data of the hydrobiological survey of Hopkins Marine Station increased in number, the true problem began to be realized.

The hydographical work (Skogsberg, 1936) disclosed that while the deeper waters of this region were characterized by a very distinct rhythm, the superficial waters were distinguished by the apparent lack of regularity in their changes, in other words by irregular fluctuations. Figure 2 illustrates the fact that there is less similarity in surface temperatures from one year to another than between deep temperatures of different years. It seems altogether possible that this fact accounts for the remarkable differences in scale features and in the growth of blue rockfish of different year classes. Because this is a shallow water species, its growth mirrored very closely the lack of regularity in its environment. Those features which usually express the rhythm of growth in fishes were found to be very poorly developed.

The writer wishes to express his appreciation for the help and encouragement of the late Dr. Tage Skogsberg of Stanford University, at whose suggestion this investigation was undertaken.

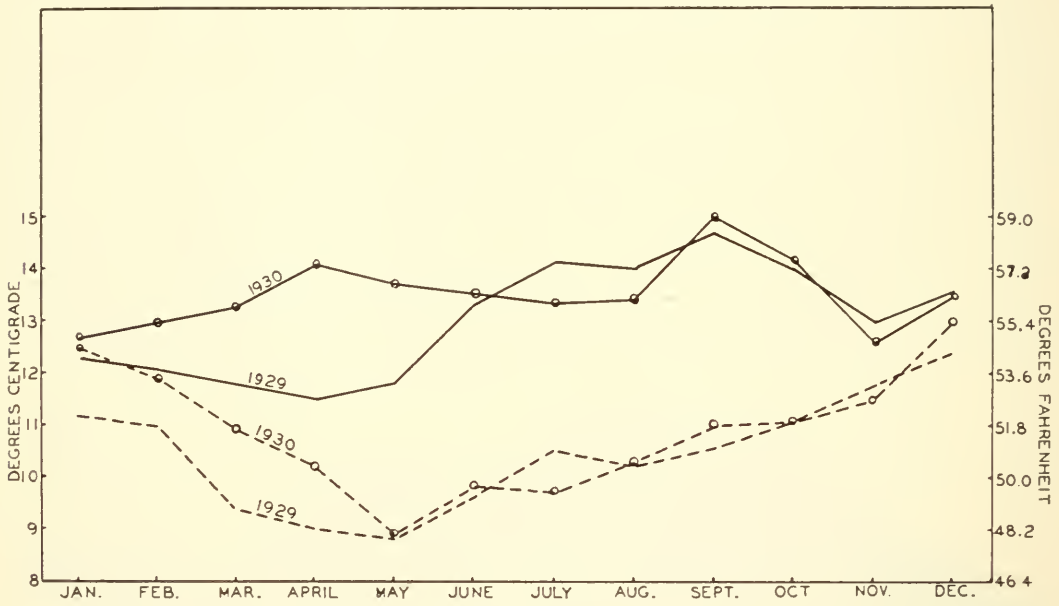

FIGURE 2. Water temperatures of Monterey Bay in 1929 and 1930. Surface temperatures are represented by solid lines; temperatures at 50 meters by broken lines.

METHODS

Most of the specimens were secured by hook and line from a skiff just off the rocks at Hopkins Marine Station, which is situated on Mussel Point, one and one-fifth miles west of Monterey, California. Nets and rockcod lines, consisting of many hooks, were tried, without reasonable success. The best gear for catching the fish was found to be a short pole with a line of equal length and one or two hooks. The bait was squid, blue rockfish, *Oxyjulis* (the señorita, a common shore fish) or sardine. The method is not only extremely time consuming but undoubtedly tends to be *strongly selective*. As a consequence, the material collected was largely of one year class and even this was so poorly represented that a good length frequency analysis was impossible.

Some samples of the commercial catch were taken at the Monterey fresh fish markets. Since these fish were known to have been caught close to the main sampling area, the writer did not hesitate to include them with the rest of the specimens.

Scale samples were taken from all fish handled. In the younger age classes about 98 percent of the samples could be read. On the other hand, many of the scales of the older, market-caught fish could not be read. In *S. mystinus* the scales seemed to be more easily read than the otoliths and opercular bones but in some of the other commercially important species of this genus well-defined rings could be found in the otoliths. This peculiarity is apparently correlated with the circumstance that the more important commercial species occur in deep water, where there is a distinct seasonal rhythm in the temperature during the year. *S. mystinus*, on the contrary, spends all or most of its life in shallow water, which in Monterey Bay is not characterized by such regular changes, but by irregular fluctuations (Figure 2). If, as is generally assumed, the rhythm expressed by the bony structures actually is the material record of a metabolic rhythm, then this differential behavior of the bony structures of these species must be considered as very strong evidence that the temperature is at least the fundamental factor in bringing about this rhythm. It should be noted that no season of the year is characterized by scarcity of food in the Monterey region.

In an effort to find out something about the rate of growth, the rate of addition of scale circuli was determined simply by counting the number of circuli on each scale beyond a certain point which was established for each year class separately. For the zero class, all the circuli were counted (Figure 6); for class 1+, all beyond "secondary ring" C (Figure 7); for class 2+, all beyond annulus D (Figure 8); and for class 3+, those beyond annulus F (Figure 9).

As has already been noted, 280 fish were tagged in September 1929, and 770 in the summer and fall of 1930. The fish were caught by hook and line, the fork length obtained, a sample of scales taken, a tag [2] attached to the operculum and the fish liberated. In the recaptured fish the tag had worn the hole in the opercle slightly larger and in some cases evidently had irritated the skin. The tags themselves often became covered with a fine growth of algae. The loss of tags is not believed to have been great.

A number of fish were retaken after having been tagged a week or two but only those which had been out for at least a month were considered in the following analysis. Seven fish tagged in 1929 were retaken by staff members of the Hopkins Marine Station from one month to nine months and twenty-five days after liberation. Ten fish tagged in 1930 were retaken by the writer within the following five months. None of these fish were out during the period of annulus formation. In other words, out of 1,050 tagged fish only 17 were recaptured and examined. Not only was this a very small number but its significance was further decreased by the facts that the specimens belonged to three different year classes and that they were recaptured during different seasons of the year and after varying periods following their liberation. However, the data obtained from the tagged fish were valuable in checking the general scale and length frequency studies.

[2] The tags were No. 3, noncorrosive metal fish tags made by the Salt Lake Stamp Company, Salt Lake City, Utah.

The average monthly growth of the tagged specimens was 2.46 mm. Assuming that there is no differential seasonal growth, this would correspond to an average yearly increment of 29.52 mm. ($1\frac{5}{32}$ inches) within the first three year classes. The supposition of uniform growth is not unreasonable. The fact that the annuli are very poorly marked indicates but a slight decrease in growth during the time of their formation.

The average increase in the number of scale circuli was 4.34 each month or 52.08 a year. The first three year classes showed no significant difference in this regard. Class 1+ added 5.7 circuli; class 2+, 4 circuli; and class 3+, 4.9 circuli per month. These latter values probably do not represent the average trend, since it would be most unusual to find a greater growth rate in class 3+ than in class 2+.

Despite this apparent aberration, a comparison with the results presented in the following pages will reveal a fair agreement between tagging and scale studies, thus showing that the former strongly substantiate the general results and conclusions of the report.

No definite information concerning the movements of this species was gained by the use of tags. This subject will be mentioned later. A few fish, both with and without tags, were kept in an aquarium for some months, but it was believed unwise to include observations made under such conditions.

GROWTH OF SCALES AND BODY

The form of the blue rockfish scale can be seen in the photographs. The most noticeable and by far the most noteworthy variations in the distance between circuli occur at the "annuli," which usually appear as more or less definite bands across the scale. As will be seen from Figure 3, the relative depth of the body in this species gradually decreases with age. Since the number of scales is the same throughout life, it follows that the growth of these structures must conform to this change in body proportions. In other words, as the scales grow larger they must assume a somewhat more elongate shape. In Figure 10 we can see what is accomplished by noticing the distance between side checks No. 1 and No. 2 as compared with the distance between annuli G and X.

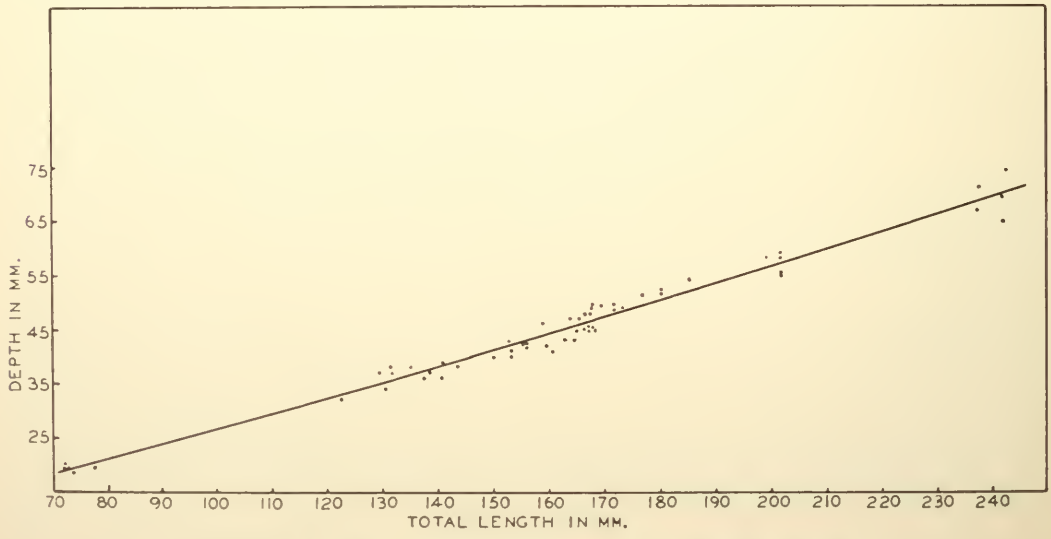

FIGURE 3. Length-depth relationship of *Sebastodes mystinus*

After the first annulus has been completed, there is a tendency for the succeeding annuli to occur as pairs of rings. The first member of each pair is the more constant (Table 1), and the more conspicuous laterally. In general, the two rings of late pairs are more widely separated than those formed earlier. Indeed, in classes 4+, 5+, and 6+ it is often impossible to tell whether two successive rings are members of a pair or true annuli of different years. I cannot explain why there are two rings in some annuli and but one in others. As a matter of fact, the cause or causes of annulus formation in *mystinus* admittedly are unknown.

TABLE 1

Occurrence of Scale Rings in the Year Classes

Ring	Year class		
	1+ 1927	2+ 1926	3+ 1925
A	98%	94%	96%
B	67%	0%	0%
C	93%	25%	21%
D		97%	100%
E		81%	17%
F			100%
G			69%

The first member of a pair is considered as a "true" annulus because of its more frequent occurrence. The others are termed "secondary" because of their irregularity. Where A or B alone was present it was impossible to tell them apart.

It was noted earlier in this discussion that there are other variations in the regular sequence of circuli besides the annuli. These irregularities may be in the form of bands (B in Figure 7) almost indistinguishable from true annuli except that they seldom have side checks; or they may occur as abrupt changes from areas of closely set circuli to areas of widely placed circuli.

No difference was found between scales of males and females.

The photographs are of selected scales and therefore give a somewhat idealized picture. However, they do not present any characters not found in the majority of these structures.

The fact that the various rings were designated by letters suggests that they could always be homologized with certainty, but this was not entirely the case. Thus in class 2+ it was very questionable whether ring A was the homologue of A, B, or C in class 1+. However, there was seldom any doubt about the years in which the annuli were formed, thus making it possible to age fish of the first four classes with very little hesitation, once the positions of the annuli were well established.

This assurance in the recognition of classes 0+, 1+, 2+, and 3+ does not apply to the older groups. There are a number of reasons for this. One has already been given, i.e., the difficulty in telling whether two successive rings represent two annuli or whether they are simply members of a paired annulus. Another reason is that beyond class 3+ the annuli

often fail to appear altogether, or they may be so poorly defined that their presence becomes a matter of conjecture.

Soon after the writer began the study of *mystinus* scales, he became aware that the establishment of similarities rather than difference was the first and most important thing. Every scale seemed to be different. Then slowly, one by one, points in common became apparent; and as the writer grew more and more familiar with the set of characters indicative of the various classes, it became easier to sort the scales, even though many cases always remained highly perplexing.

Some work was done in the matter of measuring scales from the nucleus to the various annuli. However, there was so much variation in the size of the scales that the results were nearly useless, even when a correction was made by plotting an average scale length—body length curve and then interpolating from this in the equation:

$$\frac{\text{distance to margin}}{\text{distance to check}} = \frac{\text{average distance to margin}}{X}$$

The scale's length was measured from the center of the nucleus to the middle of the anterior margin.

After having classified the fish into preliminary age groups, the next step taken was to determine the age of the smallest class, the value thus established to be used as a basis of age computation.

Of the specimens taken during June through September, 1930, the great majority formed a very pronounced size and scale group, the mode of the length frequency curve being located at 135 mm. ($5\frac{5}{16}$ inches) and the extremes at 113 mm. and 148 mm. Below 113 mm. there was a very decided gap in the frequency, the next largest specimen being only 76 mm. This fish according to the scales evidently belonged to another group, of which only six fish were taken, the smallest being 68 mm. These six fish were taken in July, 1929, and others presumably of this class were observed in tidepools in May, 1931. In other words, this smaller class occurred at the same time as the larger. The difference in age is almost certainly one year, since this species is known to spawn but once a year and the spawning season is quite short. Absolute proof that their age difference is one year is lacking, however. According to actual observations the larger group increased 40 mm. in one year. By subtracting this length from the modal length of 135 mm., we arrive at a modal length of 95 mm. for the smaller group, thus decidedly higher than the one actually observed. In regard to the number of circuli on the scales, the smaller class exhibited an average of 24, the larger, of 80. As a matter of comparison, it may be noted that the larger group added 67 circuli in one year, an unexpectedly large addition when the difference between these two length classes is taken into account.

As a matter of convenience the smaller group was called class 0+; the larger one, class 1+.

In regard to the age of class 0+, we have no direct evidence. Assuming that the growth of this class was greatest during the early part of its development, we reached the conclusion that it was derived from the previous spawning season. In other words, this class would be slightly more than six months old.

Besides the two classes just considered there were two others which could easily be distinguished on the basis of scale and size differences.

In June, 1930, the average lengths of these classes were 175 mm. ($6\frac{7}{8}$ inches) and 200 mm. ($7\frac{27}{32}$ inches), respectively. The number of scale rings in the first class was 95, while that in the larger class was 150. Undoubtedly they were older than classes 0+ and 1+, but just how much? It has already been said that the methods of sampling for a length frequency analysis were highly selective; but even though the various age groups were not sampled in a manner which would show their relative abundance, it is the writer's belief that representatives of the first four year classes were collected. From the length modes, such as they are, and from a consideration of the scales this belief seems correct beyond doubt. As no sexual differences were found in the scales and as there seems to be just one breeding season a year, we are forced to call these year classes 2+ and 3+, in other words to consider them as one and two years older than class 1+. It has been said previously that age determination at the present time cannot be carried beyond class 3+ because of lack of data and the increasingly numerous scale difficulties.

Figure 4 shows the dominant class of the 1929 collecting season falling midway between class 2+ and class 3+ of the 1930 season. Upon examination of the scales it is seen that this class is also age 2+, but it has grown faster than class 2+ of 1930.

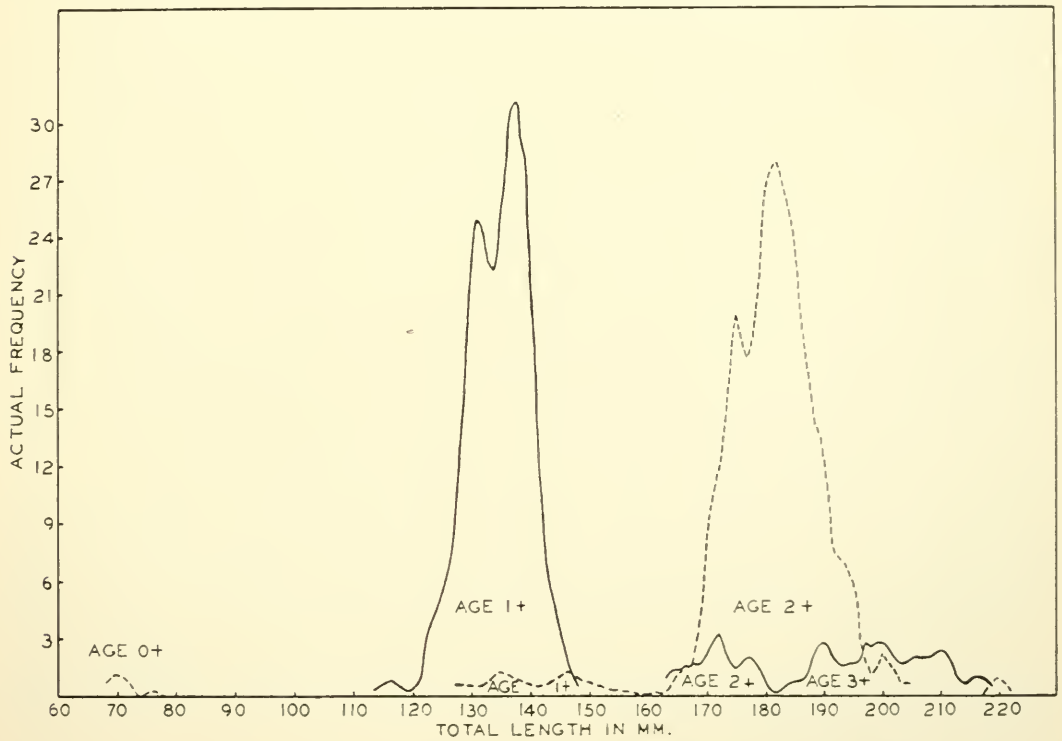

FIGURE 4. Length frequencies of the blue rockfish caught during June through September, 1929 (broken line) and during 1930 (solid line). Smoothed by a moving average of threes.

Figure 5 shows a steady increase in circuli in class 1+, but the length curve is very peculiar, doubtlessly because of the small number of fish measured. It might be asked why the circulus curve is so much better than that of the length measurements. This may be explained if we take for illustration two fish of class 1+. Fish A is 170 mm. long while B is 185

mm. In six months A has grown to a length of 185 mm. and has added 25 circuli while B has attained the length of 200 mm. and also has added 25 circuli. If small samples were made at these times they might contain fish nearly all of which were like A or nearly all like B. In either case the circulus averages would be similar but length averages would be much different.

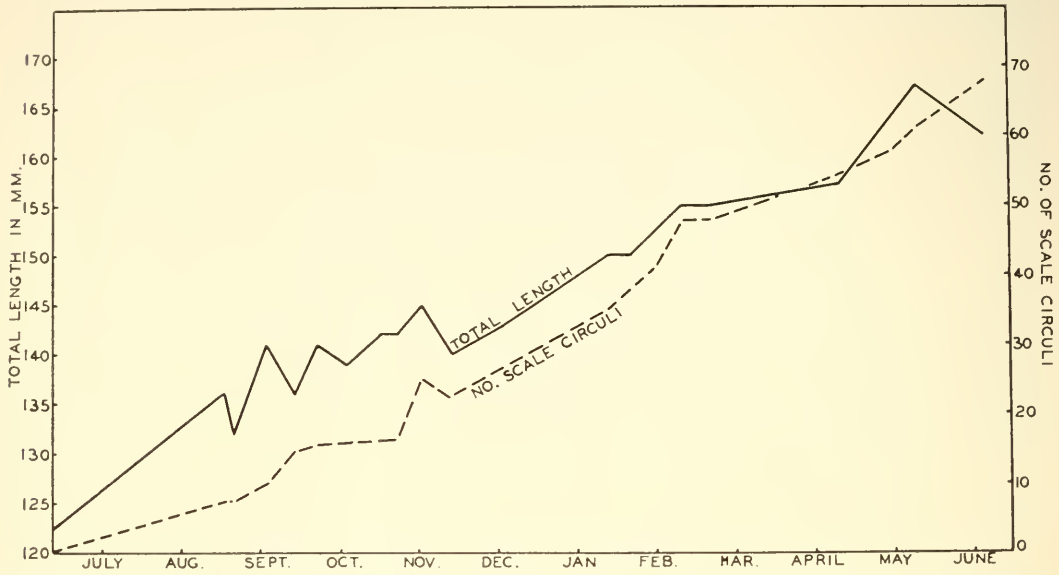

FIGURE 5. Increase in length of fish and in number of scale circuli for class 1+ during 1930-31

When regular sampling began in June, 1930, class 1+ was the youngest to be found (Figure 4). Class 1+ continued in the same relative abundance for the ensuing 13 months. In April, 1931, fish which were a year younger than this dominant class made their appearance in the area but in very small numbers. This group had very probably been present all of the time but the fish were too small to be caught. It is remarkable how much less numerous this class was than the class of the same age a year before. From this fact, it may be concluded that there is great variation in the mortality of the different year classes.

When the writer began examination of the scales of the blue rockfish in June, 1930, "annulus" C of class 1+ was forming or had recently been completed. During the ensuing year, circuli were apparently added in a very regular manner. However, at the end of the collecting in June, 1931, the scales of class 1+ taken in May and June were examined critically for irregularities, and although the irregularities found were very poorly defined, the examination showed that 31 percent had previously formed "annuli."

A little more than half of these annuli were of the single type, the rest were paired. The average number of circuli added since the completion of these annuli was seven, indicating that the annulus forming period for the fish of class 1+ which had annuli present was in March, April, and May. Contrasted with the year during which most of the fish failed to form annuli, we have the previous year and a half's growth of the same group of fish, when there were typically three "annuli" (Figure 8). Looking at the other scale photographs we can establish that the scale configurations of each year class are so unlike that we must conclude that

each year class has its own characteristic peculiarities of growth, but only in a very general way can it be said that an "annulus" is added once a year and that by counting the annuli can the age of the fish be determined. Figure 8 is an exceptional case, since it appears that each of the heavy bands is a true annulus.

This situation has already been considered, and it need scarcely be said again that we believe the irregularities in the environment of this species produce very undependable scale features for use in age determination.

SCALE CHARACTERISTICS

Realizing that the scale features in this species are somewhat confusing and that an understanding of age determination in the blue rockfish may assist in "aging" other species of this genus, it appears desirable to describe the scale photographs used in this paper more fully.

After a thorough study of the scales collected from all of the age groups found off the Hopkins Marine Station in 1929-30 it was apparent that in most cases fish of the same year class had similar scale characteristics, so that the observer could group his scales. However, it was not always possible to assign an age to these groups. Some were characterized by scales which seemed to have annular rings, but other groups did not.

In Figure 6 (1928 class 0+) the first annular ring or band started to form about twelve circuli out from the nucleus. The corresponding annulus A can be seen in Figure 7. Also in Figure 7 can be seen a "secondary" ring B, the cause of which is unknown. Frequently this so-called secondary ring is not present. In Table 1 it will be noted that in the 1927 year class this secondary ring B was present in 67 percent of the scales examined, while in the 1926 and 1925 classes this ring was altogether absent. In general it was found that when one member of such a pair was absent it was the second one formed. Therefore, I have referred to the first ring of a pair as the true annulus.

Looking again at Figure 7 it can be seen that both rings of the pair A, B were formed in the first year following the birth of the fish. The Ring C was formed in the second year. It was not followed by a secondary ring.

Now let us examine Figure 8. This is a scale from a 1926 class 2+ fish. In that year 94 percent of the fish showed the true annulus A but not the secondary ring B. Only 25 percent showed an annulus in the second year C. In its third year this class developed a pair of rings in most instances. Figure 8 shows the first of the pair D and the secondary ring E can be seen in Figure 9.

Referring to Figure 9, we see a scale from a 1925 class 3+ fish. Naturally this is a far better than average scale, selected to show all of the characters useful in aging this class. Ring A was the first of the pair commonly formed in the first year. Ring C was the annulus formed by some fish in the second year. Rings D and E make the pair formed in the third year (2+). Of this pair ring D was formed in 100 percent of the scales, while E was formed in only 17 percent of the scales. Ring F was the first or true annulus formed in 69 percent of the scales.

Figure 10 is given to show the growth between time of tagging and recapture.

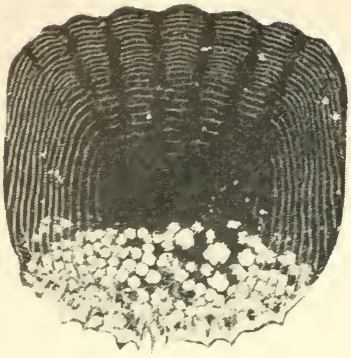

FIG. 6

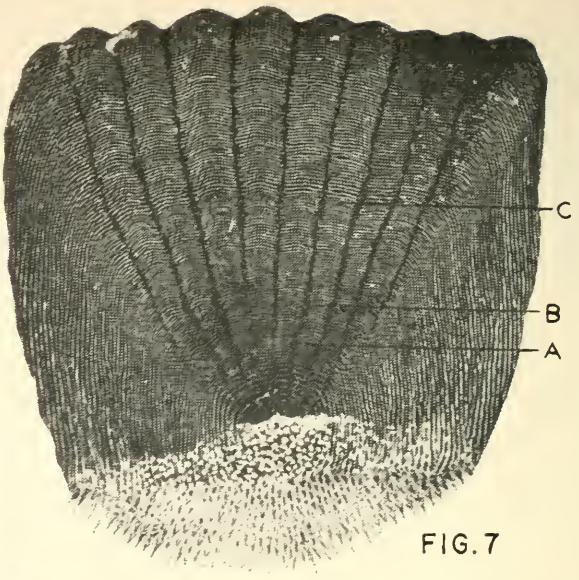

FIG. 7

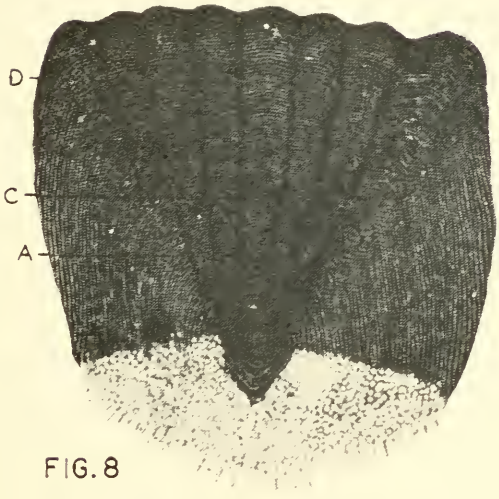

FIG. 8

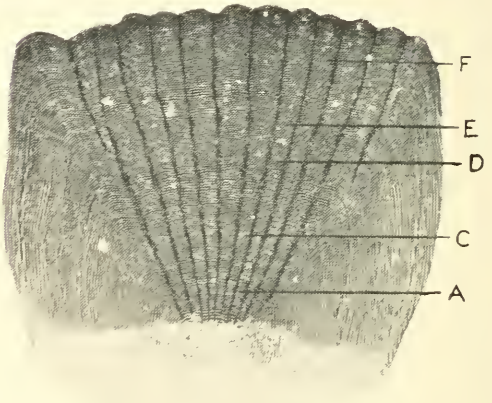

FIG. 9

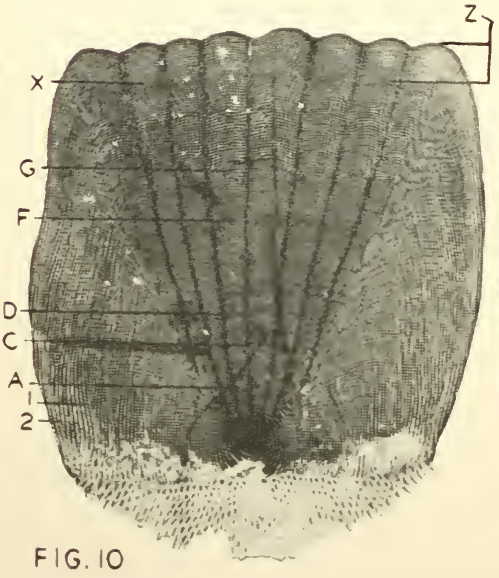

FIG. 10

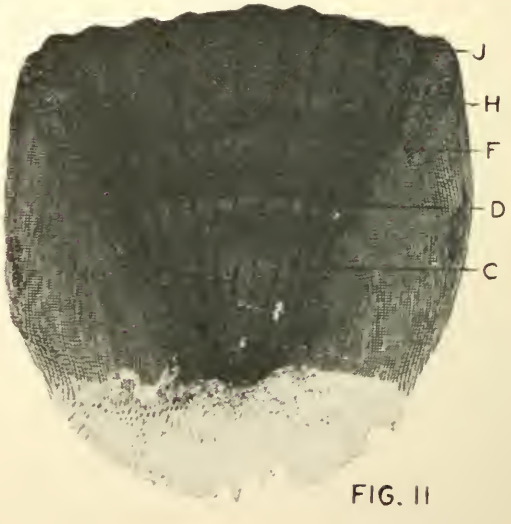

FIG. 11

Figure 11 shows a scale from a 1925 class 5+ taken in February, 1931. This is an exceptional scale. Rarely are the annuli shown this clearly. However, even in this scale the annulus for the first year is not present. However, a single broad annulus was formed in each succeeding year. It is only in rare cases that blue rockfish of this age show the annuli as clearly as does this particular specimen and even here the age determination would have been a year less than it should have been if all the younger age classes had not been studied. In conclusion, we may say that age determination from scale reading is not impossible in this species but that it is very difficult and must be accompanied by a length-frequency analysis.

EMBRYOLOGY, DISTRIBUTION AND HABITS

Some three-year-old males produce sperm, and it is probable that when four years old, most males are sexually mature. Fish with running sperm were observed as early as the last day of October.

It is probable that no females mature before they are four years old and in most cases not before the fifth year. The spawning period was found to extend through November, December, and January.

In October, eggs can be found which resemble those in Figure 12A, B. These eggs are from .03 to .24 mm. in diameter and their oil globules are colorless. In Figure 12C, the globules have become better developed and are pale yellow. These stages are found in fish of two and three years. The globules in Figure 12D are slightly yellow but those in Figure 12E are colorless. The stage represented by Figure 12E constitutes about one tenth of the eggs in an ovary which is nearing maturity. They are then about .35 mm. in diameter and probably break from the follicle when in this condition. Figure 12A-E shows the thick follicle which Eigenmann (1892) believed to be ruptured at fertilization.

Copulation seems never to have been observed in this or any other species of *Sebastodes*, but it is probably effected by a momentary contact of the genital openings. Living embryos found in females which had been dead for hours were taken from the ovaries and kept in a few drops of sea water for four hours. Figure 12F shows an embryo from a 405 mm. female taken on November 28, 1930. It was estimated that there were 524,000 such embryos in this fish. Somewhat older than the specimen of Figure 12F are the embryos in Figures 12G,H, which are from the same female. The only difference is the absence of the membrane in Figure 12H. Eigenmann (1892) believed the membrane to be broken some time before extrusion.

FIGURE 6. Scale from a 71 mm. fish of Class 0+. Caught July, 1929.

FIGURE 7. Scale from a 157 mm. fish of class 1+. Caught April 25, 1930.

FIGURE 8. Scale from a 140 mm. fish of class 2+. Caught October 7, 1930.

FIGURE 9. Scale from a 186 mm. fish of class 3+. Caught April 24, 1931.

FIGURE 10. Scale from a 202 mm. fish of class 3+. The letter Z indicates scale growth from the time the fish was tagged on September 10, 1929, when it was 187 mm. long, to the time it was recaptured on March 9, 1930, six months later.

FIGURE 11. Scale from a 230 mm. fish of class 5+. Caught on February 5, 1931.

Photographs by J. H. Wales and Wm. A. Dill

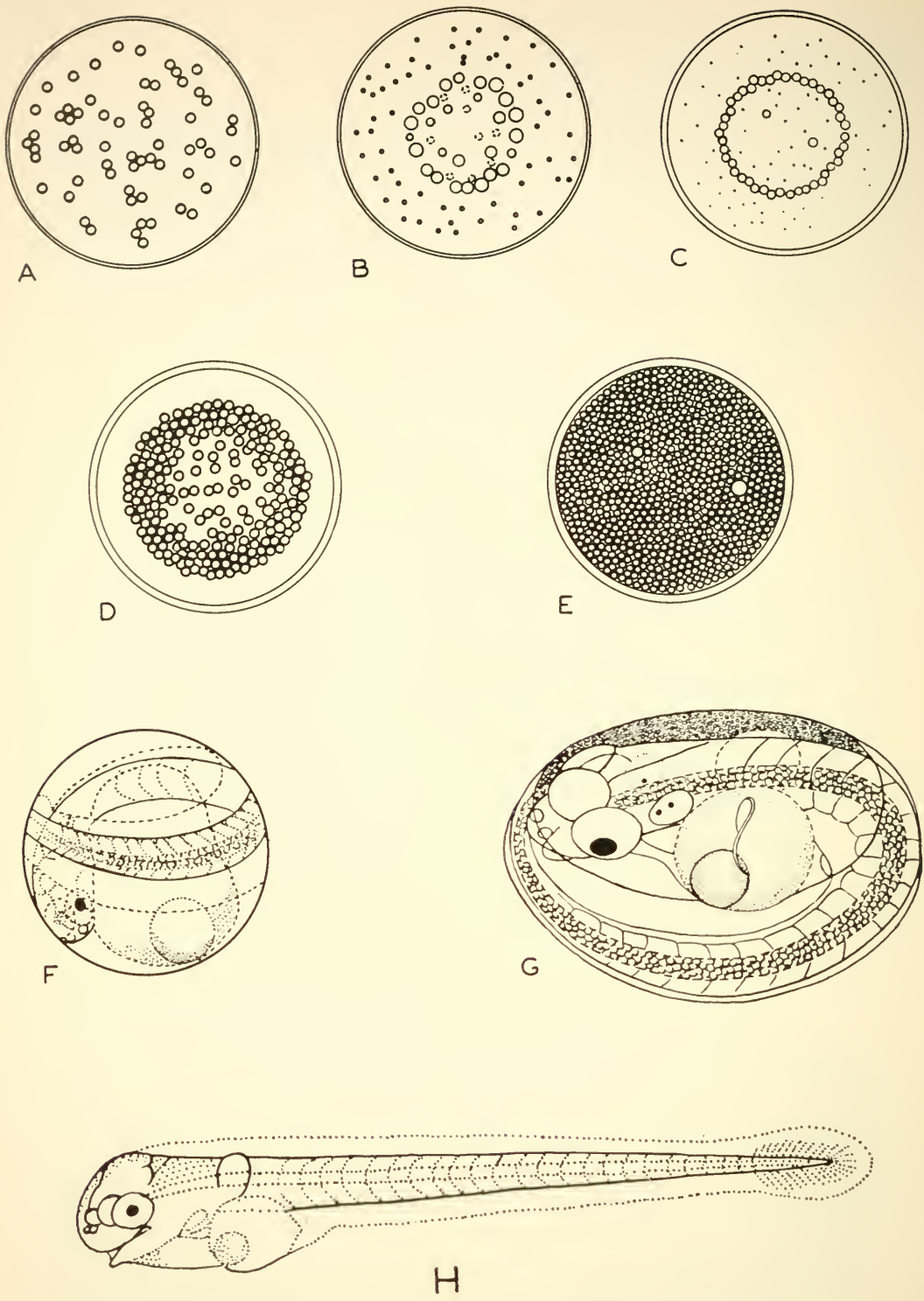

FIGURE 12. Development of blue rockfish. A. Oil globules colorless. B. Sphere of colorless globules starting to form. C. Globules pale yellow. D. Sphere of pale yellow globules growing. E. Nearly mature. Globules colorless. F. Embryo with large yolk sac. G. Embryo just prior to hatching. H. Larva just hatched.

As has already been stated, fish of the year have been seen in tidepools in May and have been taken from tidepools in July. The great scarcity of the young in the tidepools indicates that the majority are in the rocky subtidal region where it is extremely difficult to obtain them with hook

and line. The four- and six-month-old fish have a brick-red color which almost excludes the slaty black of the older fish. This red does not disappear entirely until the fish are 135 to 140 mm. long.

The young fish probably eat about the same food as the adults, that is, almost anything that they can catch in the water or nibble from the rocks. This food includes small crustaceans, crabs, and fine algae, both red and green.

The species is gregarious but the individuals do not form compact schools. At times all ages may be found in 30 to 40 feet of water, but as a rule the older fish from two years on occur in deeper water, sometimes at the surface and sometimes down to 50 fathoms. They can be caught by hook and line, but at Monterey they are taken more by the pleasure fishermen than for the markets. The reason this species is of little commercial importance is that its color is unattractive. The flesh, however, is white and has good flavor. Those which do enter the commercial catch are mostly over four years, with an average size of about 300 mm.

It is not known definitely where spawning takes place but there is no evidence that the fish move from shore at this time.

SUMMARY

1. The fish used in this study were secured near Monterey, California.

2. Scale study and length frequencies were the methods employed in age determination, although the inadequacies of sampling made length frequencies undependable.

3. The rate of increase of scale circuli was found to be a valuable adjunct to simple periodic length measurements.

4. The tagging of *mystinus* was found to be a reasonably effective check in age determination. Seventeen fish were retaken of the 1,050 tagged (1.6 percent) within 10 months of the time of liberation. In these fish there was an average monthly growth of 2.46 mm. and a monthly increase of 4.34 circuli. These values proved to be fairly close to those computed by other means.

5. Seven year classes were examined, of which the first four could easily be recognized.

6. It is probably the normal condition for one annulus to be formed each year, but sometimes three appear and in some scales none is formed.

7. The annulus may be a single ring or a pair of rings.

8. Besides the "annuli" there may be secondary rings, which tend to confuse age determination.

9. The causes of annulus formation were not determined.

10. First maturity in male fish of this species occurs in the third and fourth years, while in the females it occurs in the fourth and fifth years.

11. Fertilization is internal. An old fish may contain as many as 524,000 equally developed embryos.

12. In the year of observation the spawning began in November and extended into January.

13. The planktonic life of the young fish was not observed. Fish about five months old were the youngest seen.

14. The commercial catch consists largely of the fifth, sixth, and seventh year groups.

TABLE 2

Samples Taken During 1930-31

Date	Class 1+	Class 2+	Class 3+	
June 25, 1930	3	13		
June 30			29	
August 30	7			
September 4	65		10	
September 11			3	
September 15	116	13		
September 20			8	
September 26	36			
October 6	128		60	
October 18	14	23	15	
November 6	17		34	
November 16	17	6	6	
November 26			6	
November 28	14			
December 7			10	
December 10			10	
December 18	5	3	11	
December 26			2	
January 10, 1931			2	
January 27	33	5	4	
February 6	62		18	
February 25	13		12	
March 5	20			
April 25	44			
May 10			10	
May 15	25	7		
May 25	22			
June 22	26			
Totals	667	70	250	111*

* In the group of larger fish there were 111 specimens, of which the largest was 415 mm.

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THE TOMALES BAY HERRING FISHERY[1]

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About 30 miles northwest of San Francisco in Marin County lies the interesting body of water known as Tomales Bay. The name is a Spanish corruption of the Coast Miwok Indian word "tamal" meaning "bay." This shallow bay averages only a little over one mile wide but from its ocean mouth it extends about 15 miles southeast along the famed San Andreas fault. In the days of the buggy and surry this was a resort area. It was a one-day drive from "the city" and many San Francisco families maintained summer homes among the hills on the west side of the bay near the town of Inverness. The bay was known also as a producer of oysters and herring. In addition, it contributed small amounts of smelt, perch, white sea bass and halibut.

Through the years, herring have been caught at Tomales Bay by gill nets layed out in a circle but the bulk of the catch has been taken in beach seines when the fish were in shallow water spawning. At such times the fish were not as fat as they had been earlier in the season and this led to the belief that the gill netted fish were better for salting, smoking and "Scotch cure." For many years past, herring have been trucked to San Francisco for the fresh fish trade, as bait, for smoking and for canning. Some were trucked to Petaluma to be used as chicken feed.

The Pacific herring (*Clupea pallasi*) belongs to the herring family (Clupeidae) as do our native sardine and the introduced shad. From December through June, but mostly during January, February and March, herring enter bays at spawning time where they deposit clusters of sticky eggs on eel grass, other seaweeds or on the rocks in shallow water. For the past half century these fish have been harvested in San Francisco and Tomales Bays and more recently in Humboldt, Bodega, Monterey and San Diego Bays. Old timers in San Francisco tell of word passing from house to house that a herring boat was in and the fishermen disposed of their catch directly to the housewives at "two bits" a bucketful. In the past, most of the herring were consumed fresh but there was some salting and smoking, and at Tomales Bay there were small scale packs of "Scotch cure" herring, lightly brined and packed in tubs. As ocean sport fishing increased more and more herring were used for bait. In normal years the herring catch of the State has been a little under 1,000,000 pounds but during the four years 1916-1919 larger quantities of this fish were used for canning and for reduction into oil and meal. In the peak year 1918 the catch was about 8,000,000 pounds. Much of this poundage came from Tomales Bay.

Canning operations could utilize fish in bulk, and during the big canning years (1916-1919) most of the Tomales Bay catch was shipped out

[1] Submitted for publication March, 1952.

over the little narrow gauge line with the big title "The North Pacific Coast Railroad" which ran from the Russian River area along the coast to Sausalito. At the port of Sausalito the fish were loaded in fish boxes aboard a transport boat for delivery to the F. E. Booth cannery at Pittsburg (Contra Costa County).

The Tomales Bay herring canning was responsible for a peculiar quirk in our state laws. The then State Bureau of Commercial Fisheries was

FIGURE 1
Herring gill netter at San Francisco Bay (Richardson's Bay). *Photograph by N. B. Scofield, January, 1918.*

FIGURE 2
Herring gill netters at San Francisco Bay (Belvedere Cove). *Photograph by N. B. Scofield, January, 1918.*

FIGURE 3
Hauling beach seine for herring at San Francisco Bay (Richardson's Bay). *Photograph by N. B. Scofield, January, 1918.*

dependent, for operating funds, upon the $10 license required of commercial fishermen and a nominal packers license. It was evident that a tonnage processing tax was needed to finance the law enforcement and research so badly needed in our leading fisheries.

Such a law was discussed in 1916 and seemed to meet with general agreement but in the 1917 legislative session Mr. Frank Booth objected

FIGURE 4
Brailing herring from beach seine to lighter. San Francisco Bay (Richardson's Bay). *Photograph by N. B. Scofield, January, 1918.*

FIGURE 5
Iced herring boxed for shipment over the narrow gauge road from Hamlet on Tomales Bay to Sausalito. *Photograph by N. B. Scofield, January, 1918.*

FIGURE 6
Boxed herring being shipped to a Pittsburg cannery. *Photograph by N. B. Scofield, January, 1918.*

to the proposed 50 cents per ton tax as applying to his processing of herring and male shad. His objection threatened the life of this needed bill so a compromise was reached in which the Booth plant was excluded by making an exception in the case of herring and buck shad. The law then read all fish other than used as fresh fish and excepting herring and buck shad. The amended bill became law and went into effect in July, 1917. It remained on the books 14 years, to the mystification of many legislators, fishermen and wardens who could not understand why herring and male shad were any different than other fish. The herring-buck shad exception was dropped from the 1931-33 code.

During the 26-year interval from 1920 through 1946 there was little or no canning of Tomales Bay herring but moderate quantities continued to be sold for fresh consumption, as bait and for smoking and salting. By 1947 and 1948 the scarcity of sardines at San Francisco and Monterey stimulated interest in herring canning and these fish were being trucked to packing plants of Central California, the narrow gauge railroad having quietly expired in the meantime. R. I. P. 1874-1930. Local fishermen operating gill nets and beach seines were enjoying a more prosperous period.

Beginning in January, 1952, something new was added—the use of lampara nets for taking herring in Tomales Bay. The lampara is a roundhaul net layed out in a circle around a school of fish and pulled aboard from both ends simultaneously. They have no purse rings or other device for closing the bottom of the net other than pulling the leadline in advance of the corkline. Skill in lampara netting had been developed in the sardine fishery in the 36-year period, 1905-1940, and at Monterey a few such nets have continued in the squid fishery of that port. Also small lamparas have persisted throughout the State for catching small fish for use as bait. The typical lampara operation at Monterey, known as the launch and lighter type, includes a small power boat which carries the net and also tows a small lighter into which the catch is brailed from the net. A half dozen lampara launch and lighter rigs from Monterey Bay went north to Tomales in January, 1952, and by mid-February there were nine such crews. They were successful in catching herring on a larger scale than was being delivered by the gill nets and beach seines. History repeated itself and the "outsiders" with their larger and more efficient gear were the targets of criticism from the local small scale fishermen. The large gear was wasteful, destructive, would ruin the fishery and would deprive local men of a livelihood. This pattern of criticism aimed at the introduction of new types of gear was established so long ago that its origin is lost in unrecorded history.

Not only were the lampara nets larger and capable of landing larger catches but the lampara boats were equipped with gurdies or powered drums over which the net wings could be pulled by power from the launch engines. A still greater advantage was that the launches were equipped with sonic depth finders that could be used in locating fish schools that gave no surface indication of their presence. The herring seemed to seek deep holes waiting for actual spawning time and the lampara crews were able to find them and make catches at times when gill and beach nets could not operate.

The lampara launches used at Tomales averaged 36 feet long and each carried a five-man crew. The lighters had a capacity of 20 to 30 tons of fish and the usual lampara catch was from 10 to 30 tons with an average of about 15 tons. After locating a herring school the nets were laid out in the usual counter clockwise direction, hauled alongside the launch and the catch was brailed into the lighter. The lampara nets were bait or squid nets already possessed by these crews and averaged considerably smaller than the typical 200 fathom sardine lampara. These nets used for herring averaged about 110 fathoms around the corkline. A typical net measured 30 fathoms over the bag with each wing 40 fathoms (total 110). The mesh size of the bag was seven-eighths or one inch and twine weight was No. 20/6, which means six threads of 20-gauge cotton fibers. This is smaller than the standard 10-gauge fiber. The apron or floor of the bag was No. 6 twine of four-inch mesh. Mesh size of the lampara wings was not graduated from base to tip but was uniformly six-inch mesh throughout and made up of six-thread twine.

One "outside" boat fishing herring at Tomales (February 12, 1952) was using a "baby" purse seine only 80 fathoms long. There was no turntable and the wing was pulled in by gurdy. This net was not successful for herring and the skipper discarded it for a lampara. This miniature purse seine was operated by a four-man crew.

The herring beach seiners (1952) at Tomales employed a small launch to tow the seine skiff and a flat-bottomed barge about 12 by 30 feet in size and capable of holding 16 to 18 tons of fish. The net was stacked on and shot from a skiff and when the beach haul was made the launch towed the barge to the net and the catch was brailed from the net to the barge. The barge was then towed to a shoreside hoist where the catch was loaded into trucks for delivery to San Francisco or Monterey Bay ports. The net was hauled by a four-man crew without windlass or other mechanical power. Normally there were four to seven herring beach seine crews at Tomales. These herring seines ranged in size from 70 to 100 fathoms of corkline with 85 to 90 fathoms as average size. Like the Italian "chinchola," these seines had a deep bag. Mesh size in the bag was 1½-inch and the bunt was 400 meshes deep by 275 long (fore and aft). The wings were of four-inch mesh tapering at the ends to an 18-inch spreader called "the stick." The average seine was made up of nine-thread cotton twine throughout the net. Some seines were hung with a strip of heavier selvage, four or five inches wide, along the leadline but not at the corkline. However, most herring beach seines were hung without selvage on either cork or leadlines.

At Tomales there has been some beach seining for salt water perch. The nets are similar to the herring seines in length but only about one-half as deep with 2½-inch mesh in the bag and four-inch in the wings. Only occasional beach seine hauls were made for smelt. These fish were caught in gill nets laid out in a circle using 2-inch or 2½-inch mesh. Two 30- to 35-fathom pieces, locally called "shakles" were fished as a string and sometimes one boat ran two strings of shackles. These gill nets were not left overnight but were worked continuously. Some perch were taken in drift, three-wall, trammel nets whose inner walls were 20/9-thread with 18-inch No. 9 outer guards.

In the last five or six years local fishermen at Tomales have not found white sea bass but they used to fish for them with eight-inch mesh drift gill nets made up with Italian hemp webbing. These nets were allowed to drift all night and were worked the following day. The shackles were 30 to 35 fathoms and three to six were fished as a string. The halibut trammel nets fished locally were eight-inch No. 9 inner wall with 32-inch mesh No. 9 guards. These usually were fished outside the bay in which case they were anchored overnight. The law prohibits set nets in the bay.

Bodega Bay is about 10 miles north of Tomales and in January, 1948, herring beach seining was similar to that conducted at Tomales Bay. A launch towed the seine skiff and flat-bottomed barge. Seining was done almost entirely at night with a two-man crew pulling a net 70 fathoms long by $3\frac{1}{2}$ fathoms deep. Catches were trucked to San Francisco. The seine bag was of $1\frac{1}{2}$- or 2-inch mesh. The body of the seine was $2\frac{1}{2}$- or 3-inch and the wings were of $4\frac{1}{2}$-inch mesh.

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LIFE HISTORY AND PRODUCTIVITY OF A POPULATION OF WESTERN MOURNING DOVES IN CALIFORNIA[1]

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INTRODUCTION

The western mourning dove (*Zenaidura macroura marginella*) is California's most widely distributed game bird. Its range extends throughout the State and on all southern coastal islands. Breeding has been observed altitudinally from sea level to 10,300 feet (Grinnell, Bryant and Storer, 1918). Most nesting, however, occurs in the bottomlands, orchards and sparse chaparral areas of the Lower and Upper Sonoran life-zones.

To evaluate briefly the dove's wildlife resource value in California, one need only to check the number of doves taken each year in the hunters' bag. Hjersman (1951) has shown that the state-wide dove kill in 1948, computed from a post card hunter survey, approximated 2,378,000 birds taken by about 161,000 hunters. This may be high, however, as subsequent annual figures approximate 2,000,000 birds. This places the mourning dove as the leading upland game bird in California, in terms of numbers killed.

Little has been reported on the life history and productivity of this dove in California. The present study records data on these subjects which were obtained from May 1, 1948, through April, 1952, at Gray Lodge State Game Refuge, Butte County, California. Supplementary information has been obtained from a review of pertinent literature and from general observations made in the Sacramento and San Joaquin Valleys as opportunity permitted.

ACKNOWLEDGMENTS

This study was conducted in partial fulfillment of the requirements for the M.A. degree at the University of California. Acknowledgment is gratefully made to my friend, Dr. A. Starker Leopold, Museum of Vertebrate Zoology, University of California, for encouragement and suggestions, and to Drs. Alden H. Miller and Lewis W. Taylor, also of the University of California, for a critical review of the manuscript. Avis Cowan, the writer's wife, assisted in gathering field notes and in compiling the written data. Acknowledgment is also made to Cliffa Corson for drawing the figures and to Don Beauchamp, Charles Moon, Elmer P. Reynolds and Ken Parrish, Department of Fish and Game personnel at Gray Lodge, for reporting new nests and checking others at various times throughout the study.

[1] Submitted for publication May, 1952.

THE STUDY AREA

Gray Lodge State Refuge, where the study was conducted, is an area of approximately 2,500 acres situated in the north-central Sacramento Valley, 10 miles southwest of the town of Gridley. The elevation is from 58 to 68 feet above sea level. The refuge has been developed primarily for waterfowl with nearly 1,800 acres of pond and marshland. It contains 22 miles of roads and approximately 18 miles of ditches. Scattered fields of millet, rice, wheat, barley and milo are grown, interspersed with edgeland and ungrazed open fields. Pasture lands, cereal crops and private duck clubs adjoin the state property.

Most rainfall occurs from October through March, with an average precipitation of 22 inches. Maximum summer temperatures often go above 100 degrees F. but winter temperatures seldom fall below 26 degrees F. The principal trees in the area are the white willow (*Salix* sp.) and the Fremont cottonwood (*Populus fremonti*).

Within the study area, two small units were closely observed for information on productivity and general life history of the doves. One of these, the Willow Pond Area, consisted of approximately two acres of willows surrounding a small pond. This area is shown in Figure 1. The other unit, here called the Headquarters Area, constituted the trees and buildings of the Gray Lodge Refuge Headquarters, an area of approximately three acres. The term "refuge area" refers to all that area of Gray Lodge Refuge excluding the Willow Pond and Headquarters areas.

FIGURE 1. The Willow Pond Area at Gray Lodge Refuge, Butte County, a preferred nesting location. *Photograph by author, March 14, 1951.*

The writer, as manager of the refuge, lived within the Headquarters Area and consequently many observations were made while performing general refuge activities. Nesting checks were normally made weekly, but inspections of individual nests often were more frequent, sometimes daily. In addition to routine nest checks, 200 fledglings were banded prior to their departure from the nest.

LIFE HISTORY AND PRODUCTIVITY

Pre-nesting Status

During the winter, resident doves on and adjacent to the study area build up sizable flocks, ranging from 24 to 72 birds. Winter flocks continue through December and may reach their peak in numbers before the month is over. The largest winter flock seen was on December 16, 1951, when 72 were counted. These birds were spending much of their time loafing and feeding in a rice stubble field adjoining the refuge. Most of these doves were seemingly paired as indicated by the individual pair association within the flock. This supposition was strengthened during November and late December, 1951, when several pairs were collected from this group. An interesting sidelight is that the female of one of these pairs had been banded 16 months earlier within 300 feet of the spot where it was taken.

Courtship behavior of doves is uncommon in winter. No display was observed in the winter months, through February. Although this evidence is limited, it is my belief that the wintering dove population in general is composed of local adults, already paired.

Wintering flocks continue until late January. A shift in the feeding and loafing area is made when the food supply diminishes. About January 26th, small groups and individual pairs begin to move out from the winter concentrations and consequently the population is more irregularly distributed. These same small loose groups, along with several single birds, were observed early in February. By mid-February, however, most wintering doves are seen in pairs and though they may be associating with others, they show little inclination to stay together as a group. In late February and early March few doves are seen. They are moving about more in the late winter period than at any other time.

Cooing is usually begun on the first spring-like days in late February. The earliest cooing date was February 25, 1952. In 1949, it was February 26th. March 11, 1951, was the latest date on which the first cooing of the season was heard.

Feeding, Watering and Roosting Habits of Adult Doves

Doves are seed eaters. They consume a wide assortment of both wild and waste grain seeds (Rosene, 1939; Leopold, 1943), which are taken throughout all seasons of the year and constitute at least 99 percent of their diet. Only rarely are parts of insects found in dove crops and these are believed to have been taken accidentally. Most feeding activity occurs during early morning hours and in late afternoon. Some doves, usually single individuals, may be observed feeding intermittently throughout the day.

During the months of November and December, 1951, 22 doves were collected adjacent to the study area and the principal seeds found in their crops are shown in Table 1. Waste rice and milo were the major

TABLE 1

Principal Contents of the Crops of 22 Wintering Dove Taken During 1951 Adjacent to Grey Lodge Refuge, Butte County, California

Date collected	Number of birds	Principal crop contents
November 13, 1951	3	Milo (mostly) and Rice
November 15, 1951	2	Rice (mostly) and Milo
November 16, 1951	2	Milo (mostly), Star Thistle (*Centaurea solstitialis*) and Smartweed (*Polygonum sp.*)
November 27, 1951	2	Rice (mostly) and miscellaneous
December 29, 1951	7	Rice and Watergrass (*Echinochloa crusgalli*)
December 30, 1951	2	Watergrass and Rice
December 31, 1951	4	Rice (mostly) and Watergrass

food items taken, followed by watergrass (*Echinochloa crusgalli*) and yellow star thistle (*Centaurea solstitialis*). Other important seeds taken throughout the year as noted from various crop contents and field observations were seeds of Turkey mullein (*Eremocarpus setigerus*), waste wheat, Canary grass (*Phalaris paradoxa*), Safflower (*Carthamus tinctorious*) and Johnson grass (*Sorghum halepense*).

For watering, doves were observed to prefer areas along shallow edges of ponds or streams which were devoid of vegetation and where sand and grit were available. The Willow Pond Area had these requirements which may have increased its desirability as a nesting area. Doves were observed drinking at odd times throughout the day but water is normally taken following their feeding periods. This habit is well known to dove hunters who seek out watering holes and hide nearby, waiting for the doves to come in for water. In drinking, the desired quantity is taken at a single draught, as the beak is kept in the water until drinking is completed.

Little has been reported on the roosting habits of the mourning dove. Grinnell, Bryant and Storer (1918) and many others report that doves customarily roost in trees, but they also are known to roost on the ground. No doves were found roosting in trees on my study area. Most roosting occurred in open fields of sparse vegetation, usually pasture land grazed over by cattle or stubble hay fields adjacent to nesting or feeding area. On the night of August 25, 1949, 42 doves were flushed from their roost in an open pasture of 60 acres. These birds ranged from single individuals to loose groups numbering up to 12. During winter months it is not uncommon to observe doves roosting along old dirt roads. Even among nesting pairs, only birds that were incubating or brooding were found in the nest trees on at least eight occasions when I observed with the aid of a light. Presumably the mates were among the ground-roosting birds.

When flushed from the ground at night, doves seem to be blinded by a strong light. They commonly fly almost vertically to around 40 feet and then gradually descend with wings fluttering rapidly, in a hovering attitude. The legs are extended as though reaching for the ground, reminding one of a helicopter coming in to land.

Nesting Sites and Nest Construction

Over 75 percent of the trees on the refuge are white willow. They range in size from young saplings to 30 feet or more in height with trunk diameters up to two feet. These trees provided most of the nesting sites. Other trees used for nesting were cottonwood, Chinese elm and black locust. The willow grove environment was preferred, as most nests were found in this habitat. The average height of all nests for the years of study was 11 feet. The highest was 32 feet. Only one ground nest was found and that during August in a fallow millet field.

In California, it seems that as one proceeds south ground nesting by doves increases. In Kings County, six miles northwest of Lemoore, John D. Childers for several years has observed nearly 50 percent of the dove population nesting on the ground. In surveying the boundaries of three of Childers' cotton fields it was interesting to note that adequate nesting sites in willow groves about ponds, much like those preferred at Gray Lodge, were available. Doves move into the cotton fields during June and July before the cotton has reached its maturity. Nesting losses

FIGURE 2. Mourning dove brooding young, Gray Lodge Refuge, Butte County. This occurs almost continuously until nestlings depart from the nest at approximately 12 days of age. *Photograph by author, April 6, 1952.*

must be high as few nests can survive the cultivation practices employed in the production of this crop. After July, when the cotton plants are well established, dove nests are seldom found in cotton fields. Farther south in California, through Riverside and Imperial counties, John Laughlin, Game Manager, Department of Fish and Game, estimates that in some areas approximately 70 percent of all nests constructed are ground nests. His observations were corroborated by other wildlife technicians with experience in California's southern counties. However in areas where adequate tree sites are available the percentage of ground nests may be lower.

After the nesting site has been chosen, the nest may be constructed in one to six days, but most are completed after two or three days. Nest building takes place in the morning and lasts about two hours. Thereafter the birds usually leave the nesting site for the remainder of the day. It appears to be the male dove which gathers the nesting material from the nearby ground and carries it to his mate at the nest. She takes it and does the arranging while the male is off, obtaining another twig. One piece is carried each trip and if it is dropped the journey is continued as though the mission was to be accomplished. One pair, seemingly in a hurry, was watched for 53 consecutive minutes during which 48 trips were made. This is an average of one every 66 seconds. One journey required only 34 seconds. While seeking suitable material, the male may consume seeds encountered in the search. The selection of a

FIGURE 3. Mourning dove nest containing three eggs, Gray Lodge Refuge, Butte County. Less than 2 percent of all nests examined contained clutches of three eggs. *Photograph by author, March 30, 1951.*

nesting site may be determined by the immediate availability of nesting material. All material I saw gathered was taken within 20 yards of the nest.

Individual nests are usually loosely constructed platforms with very little elevation along the edges to keep the eggs from rolling out. Most are placed along horizontal branches or in crotches of limbs, where ease of approach and departure is provided. Old dry star thistle (*Centaurea solstitialis*) is the preferred nesting material throughout the refuge. Few nests are constructed without this material. Other nest materials consisted of weed stalks, fibers and twigs from willow trees, stems of dry oats or other similar plant materials.

After the nest is constructed and the first nesting has been carried to completion, additional nest material is almost always added to the nest before new eggs are laid. Some nest material may be added at times while incubation is in progress. Doves often use abandoned nests of other birds. Most commonly used here were those of the loggerhead shrike and western kingbird. McClure (1943) records doves also using nests of the robin, bronze grackle, bluejay, catbird, brown thrasher, yellow and black-billed cuckoos, English sparrow and domestic pigeon.

The Eggs and Incubation

Doves almost always lay two eggs at each nesting. In 303 recorded clutches, only six contained three eggs and seven were brooded with only one egg. Thus, 96 percent of the clutches were made up of two eggs. "Dropped eggs" are not uncommon in the mourning dove. Several were found around the Willow Pond area—one on a limb, one in a crotch of a willow trunk, one on the ground, and several in unoccupied nests.

Eggs are elliptical ovate, white, and measure about .83 x 1.07 inches and are laid approximately 30 hours apart. Incubation begins as soon as the first egg has been deposited except in early season nests when incubation more often begins after both eggs are laid. Incubation lasts 14 to 15 days with both male and female carrying on the incubating process. Soon after the young are hatched, the egg shells are removed by the parents.

When adults are approached and frightened from their nests, the "broken wing" ruse is often employed in an effort to lead the intruder away from the nest. This pretense of injury is shown to greater extent in the brooding period than prior to hatching of the young.

Nestings and the Nesting Season

The mourning dove has an extremely long nesting season. At Gray Lodge Refuge it begins about mid-March and continues until about September 20, a period of approximately six months. The earliest hatching date noted was March 29, 1949. The latest brood hatched on September 9 and 10, 1950, and these young left the nest on September 22. The average numbers of active nests by months for the years of observation on the Willow Pond area are shown in Figure 4. The greatest numbers of active nests were found in July, followed closely by June and August.

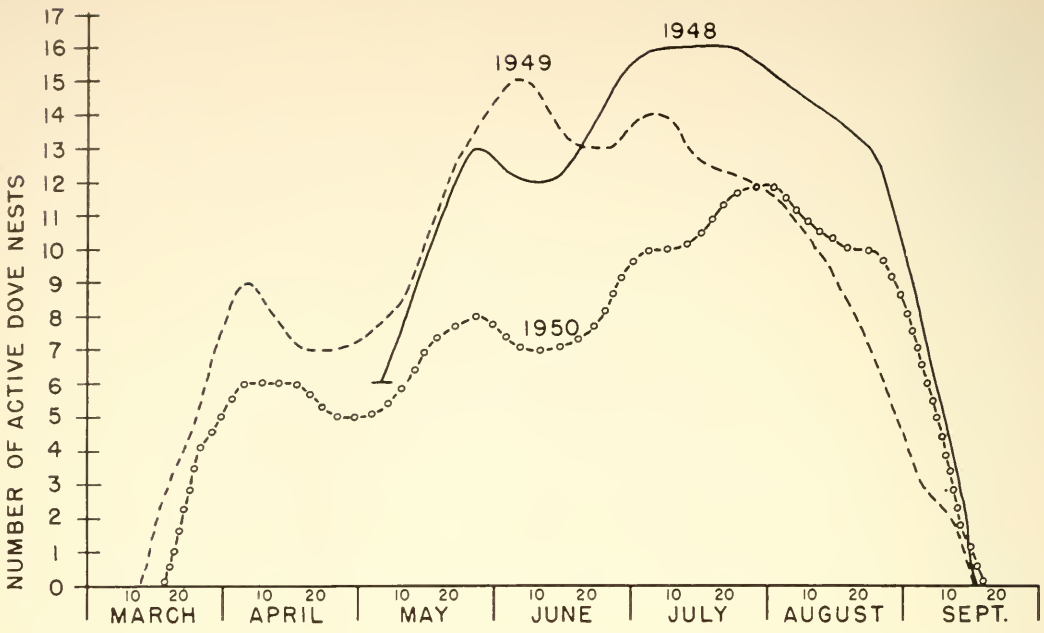

FIGURE 4. The nesting period as indicated by the active dove nests by months on the Willow Pond area

In Figure 4, a decrease in nesting activity may be seen through the latter half of April and the first week in May. This is because considerable mortality occurred among the first nests, due mainly to wind and predators. Also the greatest numbers of abandoned nests were found among early nestings, apparently due to intrusions from unmated males. Some interrupted nesting pairs underwent a short reorientation period before resuming active nesting.

Table 2 shows dates when incubation of the first nests commenced on the refuge in the years of study. Dates when last nestings of each season were completed are shown in Table 3. The latest dates of new nest construction were August 9, 1948, August 8, 1949, and August 6, 1950.

TABLE 2

Dates Incubation Started on First Dove Nests on Willow Pond Area for the Years 1949 to 1952 [1]

1949	1950	1951	1952
March 14	March 26	March 25	March 29
March 20	March 30	March 27	March 31
March 22	April 1	March 28	March 31
March 23	April 3	April 3	April 1
April 3	April 3	April 6	April 2
April 6	April 4	April 7	April 5
April 10	April 5	April 7	April 8

[1] Several of these dates may be in error by 36 hours.

TABLE 3

List of Completion Dates for Nests Active After September 1; 1948 to 1950, Willow Pond Area [1]

Dates last nestings completed			Dates last nestings completed		
1948	1949	1950	1948	1949	1950
September 1	September 7	September 2	September 7		September 13
September 3	September 12	September 7	September 9		September 14
September 5	September 14	September 8	September 12		September 18
September 6		September 10	September 14		
September 7		September 12	September 14		

[1] Completion date is that on which dove fledglings reach the age of 11 or 12 days, with possible error of one day plus or minus.

An individual nesting cycle requires approximately 30 days to complete. From 3 to 6 days are spent on nest construction and egg laying, approximately 14½ days in incubation and 11 to 14 days in brooding the young.

The number of nestings attempted in each nest on the Willow Pond area for the years 1948 to 1950 are shown in Table 4. In these years 111 nests were constructed. Fourteen (12.6 percent) were constructed but

TABLE 4

Number of Nestings in Each Nest on the Willow Pond Area for 1948, 1949 and 1950

Year	Total number nests	Total nesting attempts	Number of clutches per nest [2]						
			Not used	1	2	3	4	5	6
1948[1]	30	68	3	9	5	6	7	--	--
1949	41	77	3	18	11	5	2	1	1
1950	40	63	8	15	13	2	2	0	0
Totals	111	208	14	42	29	13	11	1	1
Percentage of total nests			12.6	37.8	26.1	11.7	9.7	0.9	0.9

[1] Incomplete because March and April nesting activity is unknown for 1948. Several nests may have been used five or six times.
[2] Some nests may have been used by more than one pair.

not used, 42 (37.8 percent) were used once, 29 (26.1 percent) were used twice, 13 (11.7 percent) were used three times and 11 (9.7 percent) were used four times. One nest was used five times but apparently by two pairs, and one was used six times, apparently by the same pair. It is believed that in 1948 several nests may have been used five or six times, but in this year nesting records were not obtained during March and April.

Since the nesting season lasts for about six months and each successful nesting requires approximately 30 days to complete, this allows time

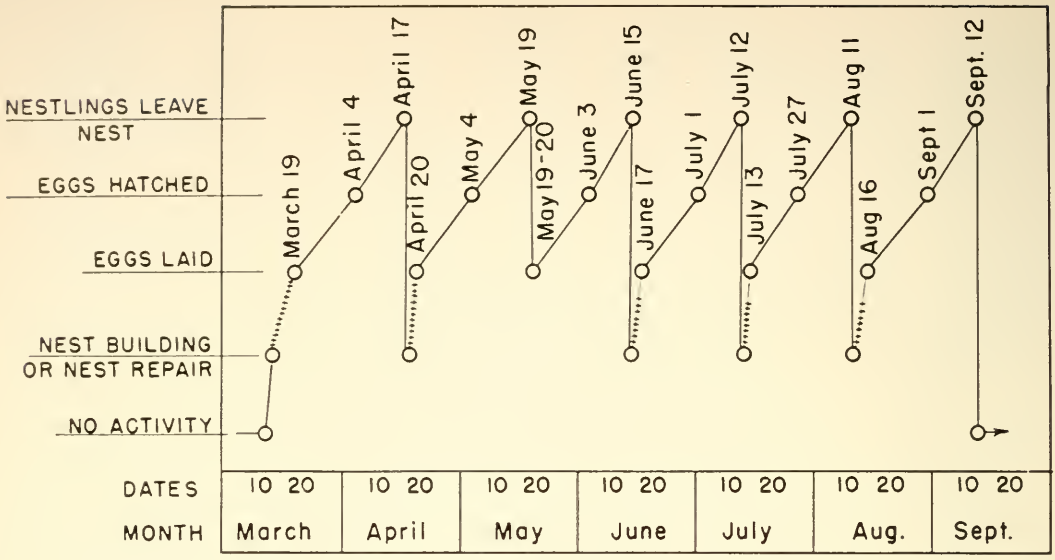

FIGURE 5. Productivity of one pair of doves (Nest No. 20, 1949) in which six broods and 12 fledglings were raised successfully

for six broods per nesting season. One pair, in Nest 20 (Figure 5) fulfilled this potential during 1949 by producing six broods, with clutches of two eggs each, and 12 young were fledged successfully. Although the parents were not marked, the succeeding nestings were so regular in sequence and so uniform in timing that I felt entirely certain that only the one pair used the nest. The periods between fledging of one brood and appearance of new eggs were 3, 1, 2, 1 and 5 days, respectively, as shown in Figure 5. In many other nests the interval from fledgings to eggs likewise was found to average 2 to 3 days. On one occasion, an egg was laid in a nest with fledglings a day before they departed. In 10 other nests in which clutches or young were destroyed, the average period elapsing before appearance of new eggs was 18 days and then apparently by another pair.

A recent report by Austin (1951) shows that "site tenacity" to the breeding territory appears to be a fixed behavior trait of the mourning dove. This behavior is the tendency of individual birds to return to the same territory year after year. Further analysis of observations here leads me to think that individual pairs commonly confine their nesting activities to very local areas. As an example, on the headquarters area each year daily activities of two pairs were observed closely. When either of these two pairs left an old nest to build a new one, it was always constructed again within the headquarters area. Furthermore, throughout the years of observation of the entire area the breeding populations have been relatively stable and construction of nests has been confined to the same general locations.

Since the hunting season opens on September 1 each year, it is significant in management to note the percentage of young in the nest after this date. For the years 1948 to 1950 a total of 194 clutches were attempted on the Willow Pond area. Of these, 21 were in progress after the opening of the dove season. This is 10.8 percent of all broods attempted.

Growth and Care of Young

Newly hatched doves weigh about 7 grams, are blind, and are covered with soft pale yellow natal down. The nestlings have an amazingly rapid development. Ten days after hatching they are capable of flying from the nest. Most leave the nest voluntarily at from 12 to 13 days. The age of nestlings can be easily determined by feather development, as described by Nice (1922). Nestlings at 12 days of age, ready to depart from the nest, average 70 grams in weight (McClure, 1943). This is over one-half the weight of adults which average 125 grams.

Dove squabs are fed on "pigeon milk," a material regurgitated by the parents which consists of a milky secretion from glands in the crop. As the birds become fledglings they are fed an increasing percentage of seeds. Feeding begins a few hours after hatching with both parents contributing. The young inserts its bill into that of the parent and the adult pumps the food with a bowing motion. When the young are small, both are often fed at the same time. Adults carry on almost constant brooding of the young until they are ready to leave the nest. No sanitary care of the nest is taken so nestling droppings remain in the nest.

FIGURE 6. Mourning dove nest with five-day-old nestlings at Gray Lodge Refuge, Butte County. *Photograph by author, April 22, 1952.*

Nest Mortality

Little evidence of mortality among adult doves was observed during this study. Only two fatalities were noted. One of these was killed on the nest by an unknown predator, as feathers and partial remains were found around the torn up nest. The other death occurred when a dove tried to fly through a barbed wire fence. Its body caught on a wire and was ripped open. The dove died as its injury was being examined.

In all the 220 nesting attemps at the Willow Pond area, 78 or 35.5 percent were unsuccessful (Table 5). A summary of the record of these

TABLE 5

Summarized Record of Mortality and Abandonment in the Unsuccessful Nesting Attempts at the Willow Pond Area, From May 1, 1948, to May 1, 1951

Fate of nesting attempts	1948[1]	1949	1950	1951[2]	Total	Percentage of unsuccessful nestings
Nest abandoned before eggs laid	3	3	8	2	16	20.5
Nest abandoned with eggs	3	9	3	--	15	19.2
Nest destroyed by wind storms	3	5	5	1	14	18.0
Known animal predation	1	3	4	3	11	14.1
Miscellaneous fates	2	4	2	0	8	10.2
Unknown mortality	4	6	4	0	14	18.0
Totals	16	30	26	6	78	100

[1] Observations began May 1, 1948.
[2] Records only to May 1, 1951.

unsuccessful nestings show that 16 nests were abandoned before any eggs were laid and 15 nests were abandoned after one or two eggs were deposited. In the latter case, several of these may more accurately be classified as "dropped eggs" in nonactive nests instead of abandoned after one egg was laid.

Doves often build light, flimsy nests which are easily destroyed by winds of moderate velocity. Fourteen of the 78 unsuccessful nestings on the Willow Pond area at Gray Lodge were due to wind storms. This amounted to 18.0 percent of all unsuccessful nestings or 6.4 percent of the 220 attempted nestings. Nice (1923) reports the loss of 14 out of 19 occupied nests following a two day storm during April at Norman, Oklahoma. In Iowa, McClure (1943) reports that the average loss of all nesting attempts through wind and weather for three years of study was 22 percent.

Known animal predators accounted for 11 nest mortalities. These included observed predation by a rat (*Rattus norvegicus*) and feral house cats. Other animals believed to have been responsible for nesting losses, from various signs recorded, include the ground squirrel (*Citellus* sp.), the striped skunk (*Mephitis mephitis*), and the gray fox (*Urocyon cinereoargenteus*). No losses were attributed to bird predation at the Willow Pond. However, two- and three-day-old nestlings were taken from their nests by shrikes in the headquarters area. Shrikes nest throughout the refuge but are not abundant. Shrikes and doves were

observed nesting within 10 feet of each other without showing any evidence of mutual intolerance.

Losses attributed to miscellaneous causes at the Willow Pond included young falling from their nests, nesting limbs breaking, human intrusions, turkeys roosting on nests, eggs rolling out of the nests, nests infested with tree ants, and pieces of bark or limbs falling into a nest. Fourteen fatalities were classified as unknown. These included such things as eggs or young missing, nests or eggs destroyed by undetermined predators, or young dead in the nest. Two of the latter were found to be parasitized by larvae of two species of blow flies (*Protocalliphora* and *Calliphora*). Whether or not the larvae actually killed the young doves was not determined. Of further interest in this case was the fact that when the nest was examined the young were still being brooded even though dead in their nest.

Production on the Willow Pond Area

The productivity of the mourning dove on the Willow Pond Area for the period from May 1, 1948, to April 30, 1951, is summarized in Table 6. In this period there were 220 nestings attempted in 122 nests. Sixteen of these nests were abandoned before eggs were laid, leaving 106 that were used. In these, 204 clutches were attempted of which 155 hatched. One hundred and forty-two of these were successful. A successful nesting is one from which at least one young is raised to the age of 12 days or more. Total nestlings raised amounted to 274.

To indicate the nesting success for these years, a computation was made which shows that 142 nestings out of 220 were successful. This is a nesting success of 64.5 percent, which exceeds the 58.1 percent observed by Boldt and Hendrickson (1952) in North Dakota Shelterbelts, the 51.2 percent success reported by McClure (1950), summarizing his studies in Iowa, Nebraska and California, and the approximate 50 percent success reported by Quay (1950) for North Carolina.

Significant is the average productivity of each nesting pair on the Willow Pond Area. Since complete data are available only for the years 1949 and 1950, the following computations of productivity are based on the records for these years. According to my records there were 15 nesting pairs during 1949 and 12 pairs in 1950. These were calculated by counting the highest number of nests in use at one time on the area during each season. This tally of active nests included nests which were in the "interval" stage of renesting following a successful nesting period. Inasmuch as the Willow Pond area was separated by more than one mile from other known dove nesting activity, it is believed all productivity of these pairs was confined to the area. The number of active nests by month is shown in Figure 4.

In 1949, 89 nestlings were raised by the 15 nesting pairs on the Willow Pond area. This is an average of 6.0 squabs raised per pair. In 1950, 12 pairs raised 79 young for an average of 6.6 fledglings. An analysis of the total nesting attempts shows an average of 5.1 nestings were started by each pair. Over three broods, therefore, were successfully raised by each pair each nesting season. As noted above, the potential production of broods by mourning doves in this area is 6 (12 fledglings), as was demonstrated by the pair in nest no. 20.

TABLE 6

Summarized Record of Western Mourning Dove Productivity on the Willow Pond Area
Gray Lodge Refuge, From May 1, 1948, to May 1, 1951

Year	Total nests built	Total active nests	Total nesting pairs[1]	Total nestings attempted	Clutches attempted	Clutches hatched	Eggs laid	Eggs hatched	Nestlings raised	Successful nestings[2]	Nestlings raised per active nest	Nestlings raised per nesting pair
1948[3]	30	27	16	68	65	53	125	105	99	51	3.7	6.2
1949	41	38	15	77	74	52	147	103	89	47	2.3	6.0
1950	40	32	12	63	55	44	108	88	79	40	2.5	6.6
1951[4]	11	9	7	12	10	6	18	14	7	4	---	---
Totals	122	106	--	220	204[5]	155	398	310	274	142	---	---

[1] Recorded from highest number of nests active at one time on the area.
[2] A successful nesting is one from which at least one young is fledged.
[3] Recorded from May 1st through nesting season.
[4] Records data to May 1, 1951.
[5] Four of these may have been "dropped eggs" instead of cases of abandonment after first egg laid.

The Nesting Census and Total Production of the Area

Any evaluation of productivity on an area involves taking a census of the breeding population. This may seem difficult in a species as mobile as the mourning dove. However, while the dove inhabits its breeding grounds, a relatively accurate index of the breeding pairs can be obtained. To accomplish this a careful census of the total dove nesting population must be made while it is at its peak of breeding activity. On the Willow Pond area this peak was reached in the period from early June to mid-August with maximum nesting activity occurring ordinarily in July. A thorough census of all nests in use on the entire study area was made in mid-July. Since some breeding pairs may be missed, due to the interval between nesting attempts, an allowance for this census error should be added to the total area count. This error was estimated at approximately 14 percent of the nesting pairs on the entire study area.

Our total breeding population was determined by adding 14 percent to the July census figure. Then, by applying the known productivity rate observed in the Willow Pond population (six young per pair) to the breeding population, the total dove production on the 2500 acre refuge was determined for each year, as shown in Table 7. The total

TABLE 7

Census of Active Dove Nests During July at Gray Lodge Refuge for the Years 1948-1951 With Calculated Production for These Years

Year	Willow pond	Hdq. area	Refuge area	Estimated census error[1]	Total nesting pairs	Total production
1948	16	2	5	3	26	156
1949	15	2	8	4	29	174
1950	12	1	11	3	27	162
1951	7	2	19	4	32	192

[1] At any given time, part of the breeding pairs will not have active nests; hence will be missed in a census of active nests. Judging from observation on the Willow Pond area, approximately 14 percent should be added to the total of active nests to obtain number of breeding pairs.

nesting population in 1948 was 52 doves or 26 pairs. Calculating six young per pair, these birds produced 156 squabs. In 1949, 29 pairs raised 174 young; in 1951, 27 pairs produced 162 fledglings; and in 1951 the peak production of 192 was attained by 32 pairs. The slight increase in the dove population is believed to be due to improved dove habitat brought about by the reclamation of solid marsh stands and increased agricultural developments. In general, however, it may be said that the breeding population on the entire area was relatively stable. The overall productivity for the 2500 acres during the study period (1948-51) amounted to 684 fledglings. This is an average of 171 doves per year or approximately one dove per 15 acres annually.

Autumn and Winter Status

Each year through August and early September, both loosely organized and well-bound flocks of doves were seen loafing along power lines and fence rows adjacent to feeding areas. Groups of 20 to 50 juveniles, formed during the summer months, were noted to frequent areas quite

apart from the nesting localities. In 1949 one concentration of 200 doves, the largest group seen, remained from August 10 to 16. Individual pairs that had not completed their nesting activities could still be observed around the breeding grounds.

Approximately 75 percent of the dove population departs in the second week of September. Only scattered singles, individual pairs and small, loose groups are seen by late September. The timing of fall migration here is essentially the same as noted in Missouri by Leopold (1943) and in Massachusetts by Austin (1951).

October is characterized by the absence of doves. Four very loosely grouped pairs were observed along the northern reaches of the refuge in 1950. This was the greatest number recorded in October for the years of observation. Normally only a pair or two, plus a stray single would be seen in this month.

In early November doves were still few in numbers and somewhat scattered. Winter groups begin to develop in the second week. These birds consist mostly of pairs, ranging in groups from nine to 27, as observed on the study area. In late November groups may develop in numbers up to 42 or more, but this apparently depends on the available food supply. In 1949 and 1950 wintering flocks did not exceed 24 doves. However, in 1951, 48 doves were observed in one concentration and this group increased to 72 birds during December, as noted above.

SUMMARY

This study presents data on the life history and productivity of the mourning dove, recorded from May 1, 1948, through April 30, 1952, at Gray Lodge State Game Refuge, Butte County, California.

Some dove flocks winter on or adjacent to the refuge. These are composed mostly of paired birds. Break-up of winter flocks begins in late January, and by the end of February or early March the first cooing is heard. The nesting period extends from mid-March to almost September 20, which is the longest nesting span of any bird found on the refuge.

Nest construction was almost always in trees, with nests averaging 11 feet from the ground. Most nests were in willows, as they were the dominant tree on the area. Ground nests are rare here.

Over 96 percent of all nests contained clutches of two eggs. "Dropped eggs" were occasionally found around the nesting areas. Nest construction normally requires two to three days, incubation 14 to 15 days, and brooding of the young continues until nestlings depart at about 12 days of age. Thus, approximately 30 days are required to complete each nesting cycle. Only brief intervals occur between these cycles.

Each dove pair attempted an average of 5.1 nestings in the course of the breeding season. Roughly 25 percent of the nesting population renested in the same nest after each successful brood, and 75 percent built new nests. One nest was used six times consecutively by one pair which raised 12 young. Ten percent of all broods raised were still in nests on September 1, the date on which the dove season opens in California.

Of the 220 nesting attempts recorded from May 1, 1948, to May 1, 1951, on the Willow Pond area, 35.5 percent were unsuccessful. Desertions, destruction by wind, and animal predators accounted for most of these failures. Nesting success on the area amounted to 64.5 percent. The average annual productivity for each pair on the Willow Pond area in 1949 and 1950 was 6.3 nestlings.

In July of each year from 1948 through 1951 a census of all active dove nests was made throughout the refuge. Total annual productivity of the 2500 acre area was determined by applying the average production of each pair on the Willow Pond to the total nesting pairs on the refuge. The July census varied from 26 pairs in 1948 to 32 in 1951. The average nesting population for the years of study was 28.5 pairs and they produced approximately 171 fledglings yearly or about one fledgling per 15 acres.

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TOOTH DEVELOPMENT OF THE NELSON BIGHORN SHEEP[1]

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INTRODUCTION

Prehistoric evidence indicates that the Nelson bighorn sheep (*Ovis canadensis nelsoni*) has been endemic to the California and Nevada deserts since at least late Pleistocene times, yet it has had but very little of the attention and study that has been given to North American big game mammals. Field studies of this most interesting animal were started on the Desert Game Range, a national wildlife refuge near Las Vegas, Nevada, in 1942. In 1943 the writer began collecting skulls of the animals found dead in the field, and obtaining data from skulls of known age as well as from examinations of living bighorns under fence at the Corn Creek Field Headquarters. Forty-six skulls were collected, from which fourteen were selected to constitute a series showing tooth development from birth to four years of age.

The data shown in Table 1 were compiled from four skulls which were obtained at birth, two days, eighteen days, and two years of age; from the examination of live animals, including three lambs at birth, one ewe lamb at two, four, eight, eleven and eighteen days, and another ewe at four months, eleven months, one year, two years, three years, and four years of age. Supplemental information was obtained from skulls that appeared normal, and were intermediate in development between skulls of dead and living bighorn of known age. The drawings of bighorn skulls were made by Mary Deming.

There is a marked degree of abnormal tooth development and degeneration in adult animals, particularly aged ones. Some teeth are deformed, others have been lost, and some skulls display incomplete sets without the alveoli present to represent the missing teeth. In addition, there is undoubtedly variation in the time element of normal tooth development among individual animals. Table 1, therefore, represents but a general time and order table of tooth development, and is not meant to be a means of determing the date of birth of an animal from an examination of the dental development.

Throughout the period of tooth development and addition there is a steady growth of the tooth-bearing sections of the skull. The first full set of deciduous, or milk teeth, are present at approximately one month of age, and consist of four incisiform teeth on each side of the lower jaw, accompanied by three upper and lower premolars. The dental formula at this time is $I—\frac{0}{3}$, $C—\frac{0}{1}$, $P—\frac{3}{3}$, $M—\frac{0}{0}$. The first full set of deciduous and permanent teeth that constitutes a full mouth is present at approximately

[1] Submitted for publication March, 1952.

TABLE 1

Tooth Development of the Nelson Bighorn Sheep
(Ovis canadensis nelsoni)

Age	Dental formula				Remarks
	Incisors	Canines	Premolars	Molars	
At birth	0/0	0/0	0/0	0/0	Incisors close to the gum surface. Premolars can be felt with the fingers, but are not through the gums.
2 days	0/1	0/0	0/0	0/0	Center pair of incisors (nippers) appear at 48 hours. Tips spread apart.
4 days	0/2	0/0	0/0	0/0	Second pair of incisors appear (first intermediates). Somewhat spread.
8 days	0/3	0/0	0/0	0/0	Third pair of incisors (second intermediates) appear above gums.
11 days	0/3	0/1	0/0	0/0	Lower canines (corners) appear.
18 days	0/3	0/1	0/0	0/0	The premolars are pressing the gums. Incisiform teeth still somewhat spread.
1 month	0/3	0/1	3/3	0/0	Premolars through the gums. First molars just below the surface of the alveoli. Incisiform teeth drawn together and overlapping each other.
2 months	0/3	0/1	3/3	0/0	First pair of molars in maxilla and mandible protruding just beyond alveoli.
4 months	0/3	0/1	3/3	0/0	First pair of molars more pronounced but not through gums.
6 months	0/3	0/1	3/3	1/1	First molars are through gums. Alveoli of second molars present.
1 year	0/3	0/1	3/3	1/1	Second molars coming to the surface of the alveoli. Nippers replaced with permanent ones.

TABLE 1—Continued

Tooth Development of the Nelson Bighorn Sheep
(Ovis canadensis nelsoni)

Age	Dental formula				Remarks
	Incisors	Canines	Premolars	Molars	
16 months	0/3	0/1	3/3	2/2	Second molars through gums.
2 years	0/3	0/1	3/3	2/2	Third molars above alveoli. First intermediates replaced by permanent pair. All premolars replaced a pair at a time with permanent teeth.
2½ years	0/3	0/1	3/3	3/3	First full set of teeth. First and second pairs of incisors are permanent. Third incisors and canines still deciduous. Premolars and molars are permanent teeth.
3 years	0/3	0/1	3/3	3/3	Second intermediates replaced with permanent pair.
4 years	0/3	0/1	3/3	3/3	Corners replaced with permanent teeth. Full set of permanent teeth now present.

two and one-half years of age, and the full set of permanent teeth does not occur until the animal is a full four years of age. After bighorn are past four years of age, wear on the teeth, then spreading, then losing teeth are the only indexes of age. These age indicators are not reliable as they are highly variable due to the difference of range conditions and the foods eaten. Spreading and loss of teeth have been found in skulls collected from the field, but the "gummer" stage, characterized by the complete loss of teeth in domestic sheep after eight years of age has not been observed in the bighorn. In evaluating "gummers" in dry bighorn skulls the field worker must allow one-quarter inch of tooth in the dry skull to compensate for that portion of the tooth that was covered by the gum. If the teeth are under one-quarter inch in length, the animal was in all probability a "gummer."

INCISIFORM TEETH

The incisiform teeth of the Nelson bighorn are normally spatulate in shape with a dished-out effect on the posterior side. In some respects they resemble a shoe horn. Progressing from the center of the lower jaw outward, the first three pairs are the incisors, and the fourth pair is classified as lower canines, although they do not differ in shape or function

from the incisors. The first, or center pair of incisors is called the "nippers." Progressing outward, the second pair is the "first intermediates," the third pair is the "second intermediates," and the canines are called the "corners."

When the incisiform teeth first appear they are spread at the tips, but by the time the lamb is a month old they have drawn together and slightly overlap each other. The overlap begins with a posterior portion of the nippers covering an anterior portion of the first intermediates. The first intermediates likewise cover a portion of the second intermediates, and this sequence follows through outward to the corners. The deciduous incisiform teeth are smaller than the permanent ones, and in a bighorn from two to four years of age, are sometimes mistaken for abnormal teeth when compared with the larger permanent ones.

Of three new-born lambs examined, two of them showed no incisiform teeth present beyond the gums, and the third had the tip of one nipper showing. The incisiform tooth development of one lamb was followed, and the nippers appeared above the gums at two days of age. This pair was followed in order by the first intermediates at four days, the second intermediates at eight days, and the corners at eleven days. These constituted a full set of deciduous incisiform teeth.

The replacement of the deciduous incisiform teeth does not start until the animal is a full year of age. The nippers are then replaced by the permanent ones. At two full years the first intermediates are replaced. At three full years the second intermediates are replaced, and the animal is a full four years of age before the permanent corners appear.

UPPER CANINES

Four out of eleven skulls of lambs under one year of age were found to possess vestigial upper canine teeth. None was found in 35 adult skulls. Two of the four lamb skulls had an upper canine tooth on each side, one had an upper canine on the right side and no visible alveolus on the left, and the fourth skull had an upper canine on the left side and no visible alveolus on the right.

The upper canine teeth examined were decidedly rudimentary in nature. They did not protrude downward, so as to be functional, but lay flat against the bone and at approximate right angles to the premolars. They protruded from the alveoli within the maxilla, and extended past the line between the maxilla and the premaxilla. The position of the upper canines prohibited them from protruding beyond the gums.

Upper canines do not commonly occur among the North American wild sheep. Benson (1943) found evidence of upper canines in only three skulls out of a total of 303 examined by him. Dalquest and Hoffmeister (1948) in a series of 37 bighorn skulls from the State of Washington found six with one or more upper canines and one with small alveoli.

PREMOLARS

All the deciduous premolars are protruding beyond the alveoli at birth, but do not extend past the gums. When the lamb is from three weeks to one month of age the deciduous premolars are functional and the lamb is eating considerable green herbs and grass. Lambs may start

eating green foods when only two weeks of age. One was noted picking at green grass at eleven days. The deciduous premolars are not replaced by the permanent ones until the animal is two full years of age, or entering its third year.

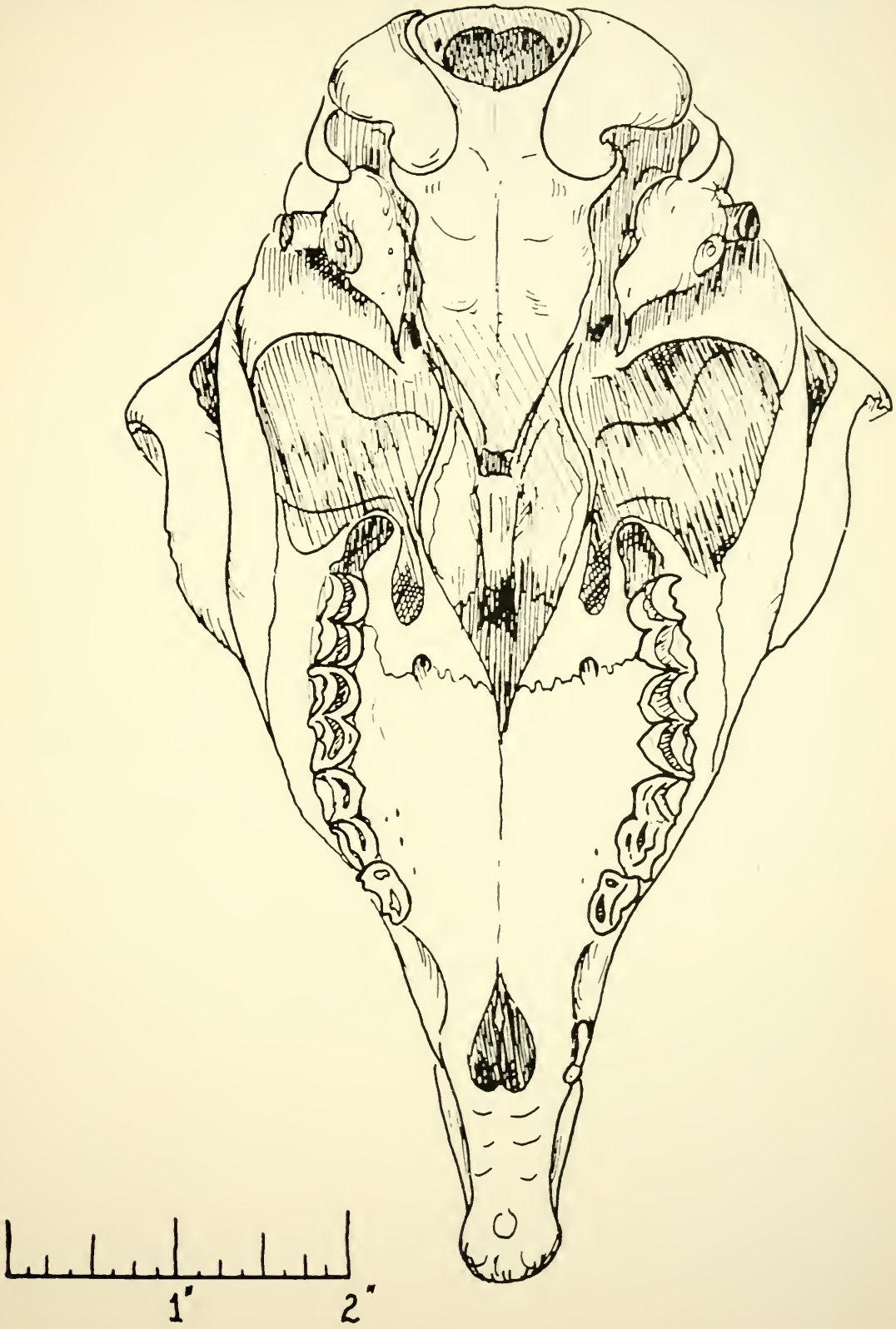

FIGURE 1. Ventral view of maxiliary dentition of young bighorn lamb showing canine

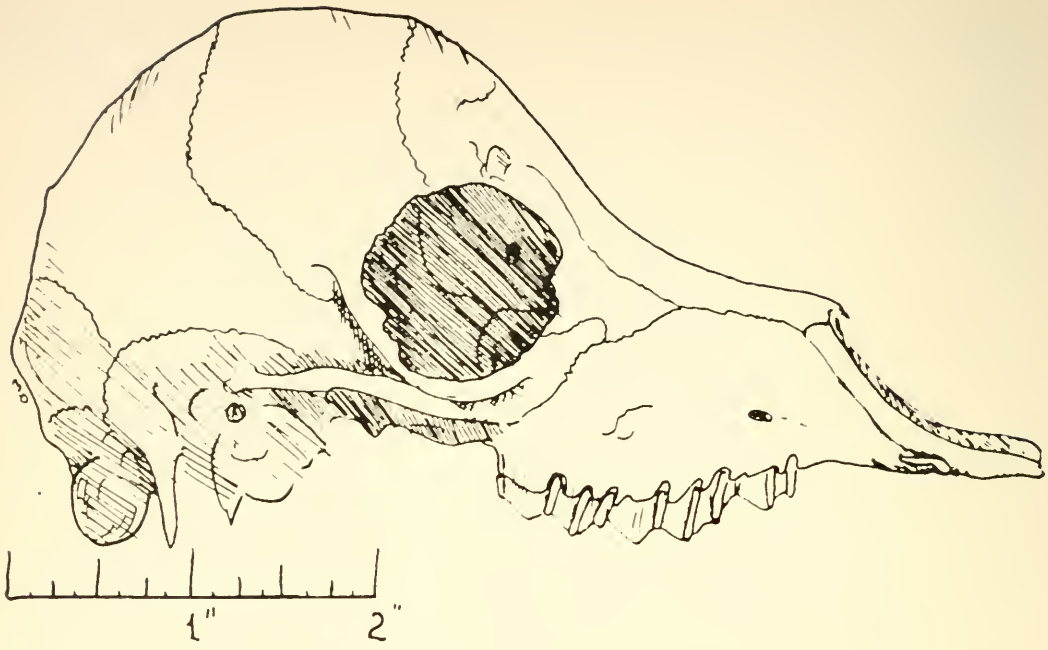

FIGURE 2. Side view of young bighorn lamb skull showing canine

In the maxilla, the first deciduous premolar has two external but no apparent internal cusps, while the second and third premolars each have two pairs of internal and external cusps. On the permanent replacement the first and second premolars have one external cusp each. The third premolar has two internal and one external cusp. The deciduous first premolar in the mandible has one external cusp and the second deciduous premolar has one external and one internal cusp, which are sometimes fused together. The deciduous third premolar is a large tooth with three external and three internal cusps. In the permanent replacement the first premolar has one external and one internal cusp, the second premolar has one external and one internal cusp, and the large third premolar is replaced with one having two external and two internal cusps.

MOLARS

There is no replacement of the molar teeth. The alveoli of the first pair are visible in the mandible, but not in the maxilla at birth. When the lamb is one month of age the alveoli are present in the maxilla, and the first molars are below the surface of the alveoli. At six months the first molars are through the gums and the alveoli of the second molars appear. At one year the second molars are at the surface of the alveoli and by eighteen months they are through the gums and the alveoli of the third molars are present. At two years of age the third molars are protruding beyond the surface of the alveoli and soon take their place as functional teeth. The first and second molars each have two internal and two external cusps, and the third molar has three external and three internal cusps, resembling in this respect the deciduous third premolar.

In the maxilla the external cusps of the entire tooth row are more prominent than the internal cusps. This is reversed in the manible, and the internal cusps there protrude higher than the external ones. As the teeth wear down there is usually a leveling of the cusps, but uneven grinding action accounts for variable wear.

EVIDENCE OF SIMILARITY

There is evidence which indicates that the tooth development of all the forms of the North American wild sheep and the domestic sheep are similar if not identical. The findings of Murie (1944) show distinct parallelism in tooth development between the Dall sheep (*Ovis dalli dalli*) and the Nelson bighorn data accumulated in Nevada. The statement of Dalquest and Hoffmeister (1948) that "the first and second incisors of a three-year old ram (no. 1804) are larger than usual, while the third incisors and canines are very small, though of normal spatulate shape" indicates that the animal had not yet obtained its permanent second intermediates and corners; that it was the approximate age as determined by horn growth; and that *Ovis canadensis californiana* also contains dental characteristics found in *nelsoni*. Likewise, the Nevada data agree in many respects with the findings of Cowan (1940) in his work with 761 specimens of the North American wild sheep. Pope (1934) describes the incisiform tooth development of the domestic sheep which is also the same as that found for the Nelson bighorn.

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FOOD HABITS OF CALIFORNIA STRIPED BASS[1]

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An opportunity arose recently to add to the fragmentary knowledge of the diet of the striped bass (*Roccus saxatilis*) in and around San Francisco Bay. Two anglers, Leon and Emil Adams, collected 387 stomachs for us in the course of a year's fishing. This report discusses their contents.

The sample is unusual, having been collected on successive Saturdays throughout the year. It should indicate in a general way what the bass population was eating at the principal times and places that the fish were being caught. The collection localities followed the principal bass migrations (Calhoun, 1952).

The stomachs were removed from the fish at the end of the day and preserved in formalin. Subsequently the contents were sorted and identified, and the numbers and volumes of food organisms were determined.

All stomachs were from fish over the minimum legal length of 12 inches. No differences of any consequence were found in the kinds of foods in large (esophagus diameter more than 0.55 inches) and small (esophagus diameter less than 0.55 inches) stomachs in this sample.

The stomachs have been divided into two groups on the basis of fishing seasons. One lot of 229 was collected during the summer and fall of 1947, in the region between San Rafael and Martinez. The other lot of 158 was from the delta portion of the San Joaquin River between Antioch and the mouth of Middle River. It was collected between November, 1947, and June, 1948. The two will be referred to subsequently simply as the "summer sample" and "winter sample," respectively.

The foods in the summer sample are shown in Table 1. They represent the principal feeding and growing season (Scofield, 1931). The uniformity was a surprise for striped bass are reputedly voracious and rather undiscriminating feeders (Shapovalov, 1936; Merriman, 1941).

Food of some sort was found in 72 percent of the sample. Shrimp (*Crago*)[2] were present in 35 percent. They represented 53 percent of all identifiable organisms by volume. They are clearly a major food of the bass population.

The individual shrimp are small, but they support a minor commercial fishery with a total annual catch currently fluctuating between 500,000 and 1,000,000 pounds. A progressive decline from about 2,500,000 pounds during the 1930's (Young and Withycombe, 1949) to the present comparatively small catch suggests a possible decrease in abundance. Perhaps there is some relationship here with the recent minor decline in striped bass abundance since about 1944, indicated by catch records

[1] Submitted for publication June, 1952.
[2] No attempt was made to distinguish the three species of San Francisco Bay shrimp, *C. franciscorum*, *C. nigricauda*, and *C. nigromaculata*.

TABLE 1

Stomach Contents of 229 Striped Bass From the Summer and Fall Fishery

Item	Incidence		Volume (cc.)	
	Times found	Percentage occurrence (in total sample)	Total in all stomachs	As percentage of identifiable material[1]
Shrimp (*Crago*)	80	35	557	53
Anchovy (*Engraulis mordax*)	26	11	410	39
Isopods	14	6	12	1
Crabs	6	3	24	2
Mysid shrimp (*Neomysis*)	4	2	14	1
Bullhead (*Leptocottus armatus*)	2	1	18	2
Flatfish	1	0.5	14	1
Smelt	1	0.5	3	0.3
Total identifiable natural food	--	--	1,052	--
Sardine bait	53	23	750	--
Unidentifiable digested material	69	30	692	--
Empty stomachs	65	28	--	--

[1] Sardine bait not included.

(Calhoun, 1949). A study of these shrimp now being made by Dr. E. S. Herald of the California Academy of Sciences promises to clarify the matter.

Next to shrimp in importance in this summer sample were anchovies (*Engraulis mordax*), found in 11 percent of the stomachs. Their volume approached that of the shrimp, amounting to 39 percent of the total.

Other foods were isopods, mysid shrimp (*Neomysis*), bullheads (*Leptocottus armatus*), flatfish, and smelt. They confirm the striped bass's readiness to eat almost any available fishes or invertebrates of appropriate size.

Let us turn now to the winter series of 158 stomachs. Feeding and growth are at a minimum in winter. Angling is normally poor then even in areas where fish can be taken readily in nets.

The contents of these stomachs are outlined in Table 2. Almost half (42 percent) were empty. The remains of small fish were the most important food, comprising 64 percent of the total volume. Mysid shrimp (*Neomysis*) were present in more stomachs than any other food. This is not surprising, in view of their abundance throughout the Delta. In spite of their frequent occurrence, however, the individual organisms are so small that they could scarcely be a major food for large striped bass, although they are known to be important for small fish in their first year (Hatton, 1940).

TABLE 2

Stomach Contents of 158 Striped Bass From the Winter and Spring Fishery

Item	Incidence		Volume (cc.)	
	Times found	Percentage occurrence (in total sample)	Total in all stomachs	As percentage of identifiable material[1]
Neomysis	31	20	74	20
Shrimp (*Crago*)	12	8	48	13
Isopods	5	3	1	<1
Smelt	3	2	6	2
Stickleback (*Gasterosteus aculeatus*)	1	1	<1	<1
Remains of small fish	14	9	235	64
Tule fragments	1	1	3	<1
Total identifiable natural food	--	--	367	100
Sardine bait	45	28	803	--
Unidentifiable digested material	50	32	393	
Empty stomachs	66	42	--	--

[1] Includes remains of small fish but excludes sardine bait.

The tule fragments (*Scirpus*) were probably swallowed incidentally, along with other food, although it is not unusual to find vegetable material in striped bass stomachs (Shapovalov, 1936; Hatton, 1940).

These two series of stomachs are indicative of feeding habits in and around the principal fishing grounds. Unfortunately, there is no way to sample the many fish which are foraging widely during the summer in areas where few or none are caught.

Another limitation of our sample stems from the inclination of schools of striped bass to feed intermittently (Merriman, 1941). Many of the bass caught by anglers have just begun to feed on chum or bait, after thoroughly digesting their previous natural meal. The large quantities of sardine bait found confirms this. It is of interest in this connection that 31 of 43 stomachs from angling-caught bass taken previously in the same general area were empty (Shapovalov, 1936). Similarly, Hatton (1940) found 57 percent empty stomachs in 224 gill-net caught bass from the mouth of the Delta in the spring.

It is apparent that the striped bass stomachs which can be obtained are not going to provide an adequate picture of the food sources of the adult population, no matter how large the sample is. Work with them has accordingly been discontinued.

SUMMARY

Shrimps (*Crago*) and anchovies (*Engraulis mordax*) were the predominant foods in 229 striped bass stomachs from the summer and fall fishery in San Francisco Bay and adjacent waters. Small fish predominated in 158 stomachs from the winter fishery.

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A SAMPLING PROGRAM FOR RECOVERY OF MARKED KING AND SILVER SALMON[1]

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Hallock, Warner and Fry (1952) told of the origin of the Pacific Marine Fisheries Commission's salmon marking program, and of the actual capture and marking of fingerling salmon as carried on during 1950 and 1951. The present paper is concerned with recovery of these marked fish and with sampling the commerical catch of salmon in California.

PURPOSE OF PROGRAM

The primary purpose of the marking program is to determine the contribution of major spawning streams to the ocean catch. For example, it will endeavor to establish where Sacramento River salmon are taken in the ocean and in what numbers.

There is much other information which can be obtained from the marking and mark recovery program. For example: king and silver salmon have different life histories, and present vastly different management problems. We need good records of the landings of each, but the species separation currently being made by dealers is so unreliable that it is useless. The sampling, which is a necessary part of the mark recovery, is already giving us a start on such separation.

Some of the other information which we hope to obtain includes: direct comparison of hatchery and wild fish through out their life cycle; a good library of salmon scales of known age and early life history; added information on growth rate; determination of the survival of individual year classes of fish; changes in the average weights and length frequencies of salmon landed at different ports. Even if there were no marking program, it would be necessary to have a sampling program to obtain part of the above data.

BASIC PLAN FOR RECOVERY OF MARKED FISH

In conducting a marked fish recovery program, it is possible to obtain returns either from fishermen and fish processors or from trained observers employed to examine the fish for marks after they are delivered; occasionally, both methods can be combined. Whenever quantitative estimates must be based on recovered marks, it is necessary to depend primarily upon men employed and trained to do the work. The reason for this can be made clear by an example. Suppose 100,000 salmon are landed at a port; samplers examine 10 percent of them and find 50 marked fish. It can then be calculated that approximately 500 marked fish were

[1] Submitted for publication March, 1952.

present in the port's entire catch. However, even if fishermen and fish processors should turn in more marks than the samplers, there is no satisfactory way of estimating the number of marks they missed, or the number of unmarked fish they examined to find the marks.

For the reasons just given, the present mark recovery program is depending entirely upon recovery by our own samplers. Marks turned in by others will be gladly accepted and information given about the origin of the fish, but no rewards are being offered and no publicity campaign is planned.

Time and Place of Sampling

In 1948 and 1949, the salmon catch at Eureka was sampled although no systematic searching for marks was done. In 1950 a general survey was made of processing practices in the salmon industry in all major salmon ports. In anticipation of the forthcoming mark recovery and sampling necessitated by the Pacific Marine Fisheries Commission's marking program, experimental work was done that year to develop tools and techniques that would make satisfactory recovery and sampling possible.

In 1951 a dress rehearsal of the program was tried. Although the fish marked by the Pacific Marine Fisheries were too small to be expected in the commercial catch, it was believed desirable to correct any major flaws in the system before these fish became numerous in the catch. Over 240 marks from various independent marking experiments were found. The experience, as well as the information collected, certainly made 1951's sampling worthwhile.

Sampling has been done in twelve ocean ports from Monterey to Crescent City, and in four Sacramento-San Joaquin Delta ports. Experience has shown that sampling should be done in the following areas: (1) Crescent City-Eureka; (2) Fort Bragg-Point Arena; (3) Bodega Bay-Point Reyes; (4) Princeton-Monterey; and (5) Martinez-Pittsburg (in the Sacramento River Delta). These are not rigid boundaries, but illustrate the range of efficient coverage by a sampling crew.

Under normal circumstances, each of the first three areas should have a sampling crew working during the summer. Only a single sampler is needed south of San Francisco. In this area, almost the entire catch is king salmon, and thus species separation is no problem. Efforts of this sampler can well be divided between the ocean and the Sacramento-San Joaquin Delta. The southern ocean fishery usually declines markedly before salmon enter the delta in any number. Occasionally, it may be necessary for more than one crew to work in the same area should the catch become so localized that this would be efficient.

Personnel Requirements

The recovery-sampling program is designed to examine at least 10 percent of the State's commercial salmon catch. During the summer, this will require full time effort of one staff biologist plus half the time of another. In addition, it should have the full time effort of six additional men. (These need not be biologists but can all be temporary seasonal aids, though it would be better if one or two were permanent employees.)

The salmon fishery is very flexible; this program has been designed to be just as flexible. Obviously, if the program is to function properly, the samplers must be alert for major shifts of the fishing fleet, and must be ready, willing and able to follow it. In finer detail, the samplers must determine at which dealer in each port they can most efficiently spend their time under a given set of circumstances.

Equipment Used

A description of the equipment and forms used is appropriate at this time. In addition to rubber boots, apron and protective sleeves, the sampling crews are issued a double hand tally, a metric pocket rule, a measuring board, recording forms, and scale collecting envelopes. The first three items need no explanation to anyone who has seen a fish processing crew at work. The double hand tally is used to keep a separate count of the two species of fish. The measuring board is used when length frequency samples are being taken. At other times the pocket rule is used to measure marked fish.

The form most used is the daily catch examination record. The following data are recorded: port of landing; date; dealer; sampler; Fish and Game number of the boat; catch area; species; total number of each species examined; number of marked fish found; weight of the catch (by species when possible); condition of the fish, i.e., round, dressed head on, or dressed head off; and the corresponding length sample number when length samples are taken. A note about weather conditions and an estimation of the total number of boats fishing from the port are also recorded.

The measuring board described below was developed through necessity. When the early survey was made, it soon became apparent that it would be necessary to have a system of measurement and recording which could be used in wet places by one man with speed and accuracy.

After several false starts, the present method evolved. In essence, it is quite simple, its main advantage being that the time consuming process of measuring and recording has been condensed into one operation.

Sampling Procedure

Speed is the keynote of salmon handling, and the sampler also must be fast—otherwise, he is apt to find, for example, that the large fish have been sorted out, iced, boxed and even shipped before he has had a chance to examine them.

This emphasis on speed often makes it impossible for a single sampler to do a good job. Two men working as a team can do almost twice as much and do it a great deal better. Usually such a team can do their work so fast that fish butchering operations are not hindered, but often a single sampler cannot.

A typical sampling procedure is as follows: One man separates and tallies the fish by species, obtains the weight of the entire catch from the weighmaster and records other necessary data. The other sampler examines the fish for fin marks and (if possible) weighs all the fish of whatever species is in the minority.

When length sampling is being done, the following procedure has been found to work satisfactorily: Before a length sample is started, a

strip of plastic four inches wide is fastened to the bottom of the measuring board. As each fish is slid onto the board, its nose is placed against the board's head block and its tail over the plastic. A short pencil mark on the plastic records the length to the fork of the tail fin; a different mark is used for each species. While one man examines for marks and slides the fish onto the measuring board, the other man records length and species, and slides the fish in a position ready for cutting to the butchers.

Transposing the pencil marks on the plastic strip into a length frequency record is done later at the sampler's leisure with the aid of a transparent plastic template accurately inscribed at half centimeter intervals. This template is placed over the strip of marked plastic, and the number of pencil marks between each two lines on the template is totaled and recorded at the proper length interval on a record sheet. For example, the template is so placed that the mark for a fish which would measure exactly 70 centimeters falls at the midpoint of the space similarly labeled on the template.

Marked fish are put aside for a more complete examination when time permits. Scales are taken to establish the age of the fish, and thus serve as a check on the validity of the mark. The place and date of recovery is recorded, as well as the weight of the fish, length, sex and species. Also recorded is the particular combination of missing fins and the percentage of regeneration. The above data are recorded on an envelope in

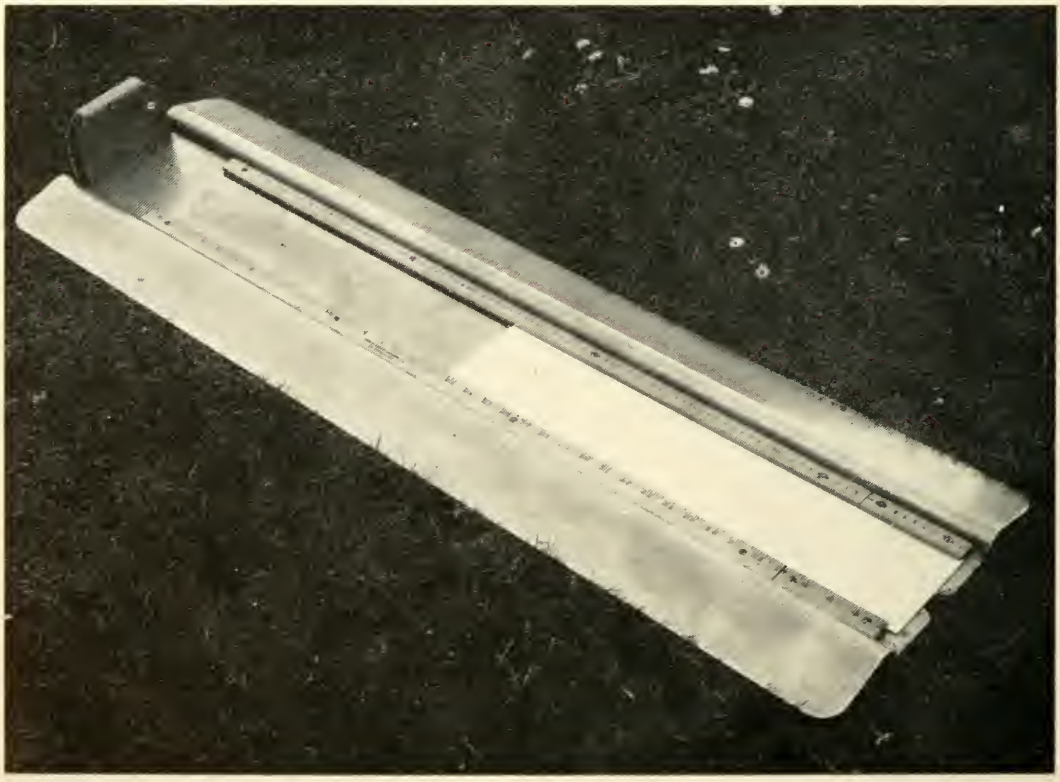

FIGURE 1. Aluminum measuring board for salmon sampling. The shape is such that fish slide readily into position. The snout is held against the wooden block and a pencil mark is made on the plastic sheet to indicate the length of the fish. The millimeter and inch rules are not used in routine length frequency sampling. The inch rule is convenient when some bystander wants to know the length of a fish. *Photograph by D. H. Fry, Jr.*

which scales from the fish have been placed. To insure that all the above data are collected, the envelopes have an appropriate form printed on them.

It is proving quite difficult to organize the sampling program so as to minimize bias. Small "day" boats fish one area and deliver fish at one time of day. Larger "ice" boats go farther for their catches and deliver at a different time. The size and species composition of their catches may be altogether different. California dealers sort salmon by size and sometimes by species, but are apt to mix silvers and small kings. Fishermen may or may not detect marked fish and carry them ashore to ask the samplers about them. The best method devised to date is reasonably satisfactory. It is for the samplers to examine *all* the salmon delivered to one dealer during a day. In the event that this proves impossible, the men examine the entire catch of each boat which they are able to sample. Marked fish from such boats are included in the calculation of marked to

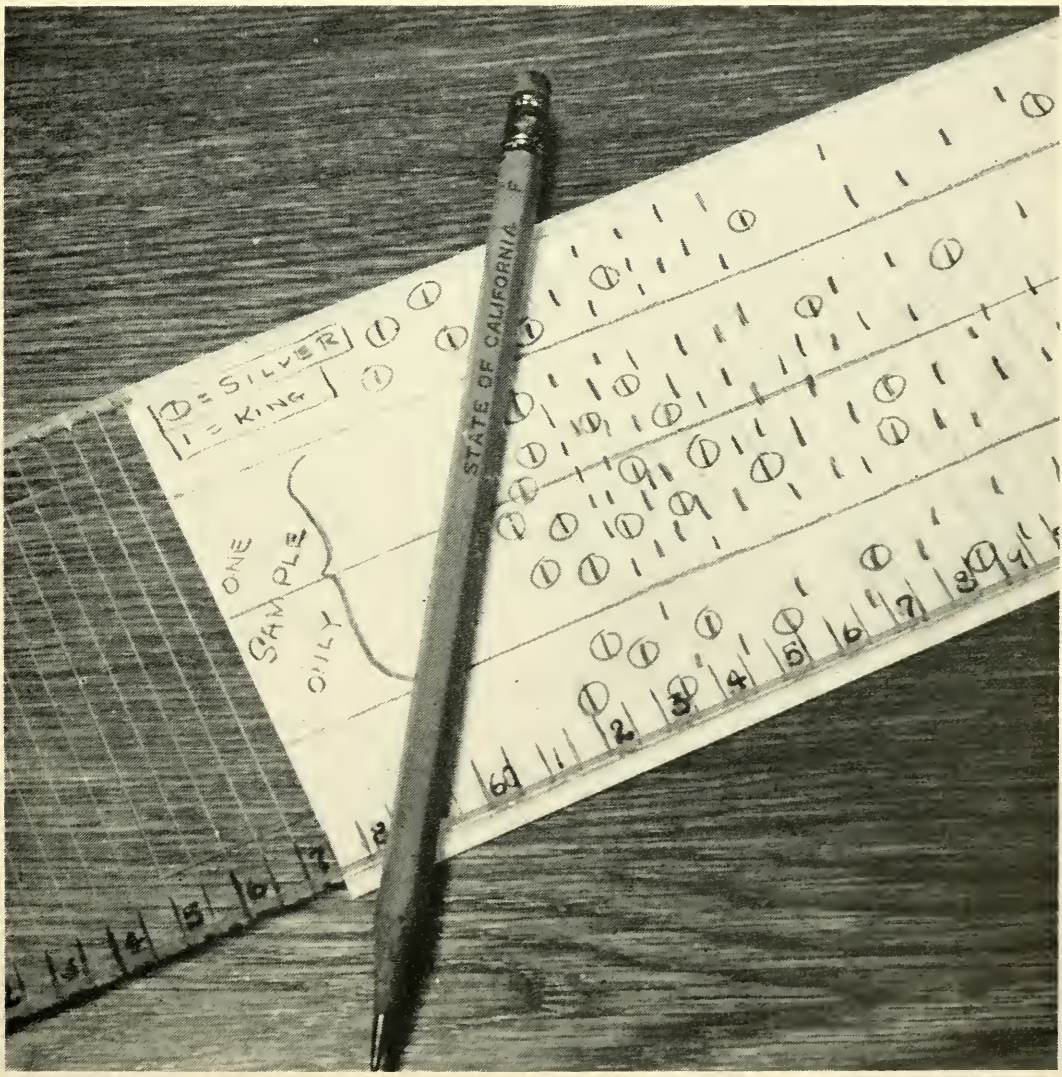

FIGURE 2. Three samples recorded on a plastic sheet. A transparent template has been placed over the sheet. The lines on the template are ½ centimeter apart. The template has a reference mark which is placed against the end of the sample sheet. Note that two different marks are used, one for king salmon, the other for silvers. *Photograph by D. H. Fry, Jr.*

unmarked fish ratios whether the fish are found by the samplers or brought to them by the fisherman. Marked fish from other boats are recorded if brought to the samplers, but are *not* included in marked-unmarked ratios.

A great deal of time and effort has gone into the marking of king and silver salmon in California, Oregon and Washington. The results obtained will depend on keeping the sampling crews alert, hard working and well organized.

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THE PISMO CLAM IN 1951[1]

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The 1951 Pismo clam census was conducted during November by the Bureau of Marine Fisheries at Pismo Beach and Morro Bay. A census has been taken at Pismo Beach each year since 1925, with the exception of war years 1942-45, and at Morro Bay since 1949. There are three sample localities at Pismo Beach (Le Grande, Oceano and Pismo), but in 1948 only the Oceano section was dug and in 1950 only the Oceano and Le Grande sections. At Morro Bay there are two sample localities (Morro and Cayucos). All sections were completed in 1951. Detailed information about former censuses has been presented by Aplin (1947), Fitch (1950) and Collyer (1951).

LE GRANDE SECTION

The Le Grande sampling line is located approximately one mile south of the broken pilings which marked the north boundary of the old clam refuge. This former refuge, a stretch of beach four miles long, was opened for digging in 1949 after a closure of 20 years. The census of 1949 (Table 1), taken about a month after opening of the sanctuary, yielded 153 clams. In 1950, 74 clams were dug; in 1951 only 23, the fewest from this section since 1928. The youngest clams in 1951 were from the 1947 year class and were four years of age. No clams were found which were older than seven, and clams of legal size were completely lacking. Failure of incoming year classes since 1948 and exceptionally heavy clamming pressure since October, 1949, have practically depopulated the intertidal area of this beach.

OCEANO SECTION

The area between the wooden entrance and exit ramps at Pismo Beach and Oceano was made a clam sanctuary in 1949 when the Le Grande area was opened. The Oceano census line is located one and one-tenth mile south of the Pismo Beach pier, about in the center of the closed area. Here, as in the Le Grande section, there has been a failure of incoming year classes since 1948 (Table 2). However, there were 144 individuals dug in 1951, only slightly fewer than the 163 and 153 of 1949 and 1950, and indicating that the closure has protected the clams in the area. Further, in 1949 only two of the 163 clams were of legal size (five inches in diameter) compared with the 20 and 26 found in the 1950 and 1951 censuses.

[1] Submitted for publication February, 1952.

TABLE 1

Number of Clams by Age Groups Taken in the Le Grande Section Each Year

Year	Age in years									Total
	0	1	2	3	4	5	6	7	8+	
1925	18	27	2	4	0	2	2	0	0	55
1926	4	10	19	0	2	1	0	1	0	37
1927	3	14	17	8	0	0	0	0	0	42
1928	0	2	5	9	1	0	0	0	1	18
1929	106	1	2	5	4	4	0	0	0	122
1930	40	36	2	2	2	3	3	0	0	88
1931	174	34	12	0	0	2	0	0	0	222
1932	13	106	32	14	6	0	2	0	0	173
1933	7	8	22	30	21	9	5	2	0	104
1934	0	5	6	9	21	10	2	4	1	58
1935	151	0	12	4	29	11	8	3	1	219
1936	0	89	1	6	4	31	18	14	12	175
1937	98	0	44	2	3	4	21	13	1	186
1938	0	23	0	39	1	4	2	3	1	73
1939	0	2	8	0	36	1	2	1	4	54
1940	0	8	4	5	0	29	9	6	30	91
1941	2	0	0	0	0	0	19	2	12	35
1942	--	--	--	--	--	--	--	--	--	--
1943	--	--	--	--	--	--	--	--	--	--
1944	--	--	--	--	--	--	--	--	--	--
1945	--	--	--	--	--	--	--	--	--	--
1946	167	47	11	17	32	12	9	6	10	311
1947	10	93	35	28	15	19	5	1	2	208
1948	--	--	--	--	--	--	--	--	--	--
1949	1	0	14	69	21	17	11	5	15	153
1950	0	0	0	5	9	25	19	9	7	74
1951	0	0	0	0	6	8	6	3	0	23

TABLE 2

Number of Clams by Age Groups Taken in the Oceano Section Each Year

Year	Age in years									Total
	0	1	2	3	4	5	6	7	8+	
1925	5	54	3	4	2	1	5	0	0	74
1926	3	2	41	2	3	0	0	0	0	51
1927	20	11	6	8	0	0	0	0	0	45
1928	0	21	15	12	2	0	0	0	0	50
1929	155	1	17	8	3	0	0	0	0	184
1930	79	65	0	2	3	0	0	0	0	149
1931	403	50	26	1	3	0	0	0	0	483
1932	14	80	39	27	10	0	0	0	0	170
1933	151	14	56	38	41	24	7	0	0	331
1934	1	46	6	34	22	8	4	0	0	121
1935	194	1	30	5	19	11	9	2	1	272
1936	83	70	1	31	3	11	4	1	0	204
1937	166	50	58	5	10	0	6	1	1	297
1938	5	65	51	33	2	3	4	0	0	163
1939	19	1	18	35	23	1	0	1	1	99
1940	17	11	2	5	17	20	1	1	0	74
1941	11	4	3	0	2	1	1	0	1	23
1942	--	--	--	--	--	--	--	--	--	--
1943	--	--	--	--	--	--	--	--	--	--
1944	--	--	--	--	--	--	--	--	--	--
1945	--	--	--	--	--	--	--	--	--	--
1946	329	115	36	54	65	7	3	0	0	609
1947	16	145	60	21	41	16	5	3	2	309
1948	0	39	97	31	21	29	24	13	5	259
1949	0	3	33	77	27	15	6	2	0	163
1950	0	1	0	17	41	39	27	16	12	153
1951	0	0	2	2	18	61	29	17	15	144

TABLE 3

Number of Clams by Age Groups Taken in the Pismo Section Each Year

Year	Age in years									Total
	0	1	2	3	4	5	6	7	8+	
1925	0	192	1	11	2	2	0	0	0	208
1926	46	3	27	1	0	0	0	0	0	77
1927	15	37	5	8	0	0	0	0	0	65
1928	6	9	20	3	12	0	0	0	0	50
1929	214	4	4	10	8	3	0	0	0	243
1930	241	87	3	0	1	1	0	0	0	333
1931	308	73	20	1	0	1	1	0	0	404
1932	17	91	54	58	12	3	0	0	0	235
1933	41	16	44	31	48	19	13	0	0	212
1934	0	19	11	38	38	13	2	0	0	121
1935	425	5	15	6	21	19	6	1	0	498
1936	61	209	1	8	2	14	6	2	0	303
1937	483	58	144	1	6	3	5	1	0	696
1938	4	145	45	103	4	4	3	3	1	312
1939	5	1	28	40	84	0	3	2	2	165
1940	8	15	5	9	12	36	1	1	0	87
1941	6	2	4	1	0	5	3	1	0	22
1942	--	--	--	--	--	--	--	--	--	--
1943	--	--	--	--	--	--	--	--	--	--
1944	--	--	--	--	--	--	--	--	--	--
1945	--	--	--	--	--	--	--	--	--	--
1946	111	5	10	133	123	32	9	2	3	428
1947	6	57	6	18	93	55	15	1	4	255
1948	--	--	--	--	--	--	--	--	--	--
1949	0	4	6	45	19	41	33	6	0	154
1950	--	--	--	--	--	--	--	--	--	--
1951	0	0	1	0	7	3	6	3	2	22

PISMO SECTION

This area, directly in front of the town of Pismo Beach, has never been closed to digging. The census line is located approximately one-eighth mile north of the Pismo Beach pier. In years past, clams of the incoming year class have been most abundant in this section, as many as 483 having been found in 1937 (Table 3). This section was not dug in 1948 and 1950 but it is certain that the set in those two years was very poor. Only 22 clams were found in 1951, which ranks with 1941 as the poorest on record. Of the 22 only one was less than four years of age while six were of legal size. This high percentage of legal clams indicates that clamming pressure has not been too heavy.

MORRO SECTION

The Morro section was first dug in 1949 shortly after a 1.5 mile stretch of beach north of Morro Rock was made a clam sanctuary. The census that year produced 77 clams (Table 4); 66 of these were four years of age or older and four were of legal size. In 1950, 32 clams were taken, all were four years and older and eight were legal size. In 1951, 60 clams were counted from this section, 16 age zero, 44 six years and older and 11 of legal size. At Morro Bay incoming year classes have not survived since 1945. Observations made on this beach in addition to the census indicate that the mortality rate among young clams is extremely high. In light of this, it seems unlikely that the 1951 year class will be in existence more than two or three years.

CAYUCOS SECTION

This section, eight-tenths of a mile north of the Standard Oil pier, was first sampled in 1949. It is an area open to public clamming and censuses indicate that it is an extremely poor clam-bearing beach. In 1949, 28 clams were dug in this section, 18 of which were zero years of age. In 1950, 3 clams were found but none was located in 1951.

CONCLUSIONS

From the 1951 census it is evident that the Pismo clam crop in the intertidal areas of Pismo Beach and Morro Bay is in a sad state. Once before, in the late 1920's, conditions were equally poor (Tables 1, 2 and 3). During the late 1920's and early 1930's there were few legal sized clams to be found, the population consisting almost entirely of clams less than four years of age. In 1951, however, it is the young clams which are lacking.

Most of the present decline in population can be attributed to three factors: failure of incoming year classes, extremely heavy clamming pressure and failure of the public to rebury undersized clams. The failure of incoming year classes, undoubtedly a normal fluctuation, could be remedied by one or two good sets of clams. Clamming pressure will probably be even greater as the population of the State increases. The present policy of opening and closing alternate

TABLE 4

Number of Clams by Age Groups Taken in the Morro Section Each Year

Year	Age in years									Total
	0	1	2	3	4	5	6	7	8+	
1949	3	0	7	1	1	33	31	1	0	77
1950	0	0	0	0	2	2	6	7	15	32
1951	16	0	0	0	0	0	8	16	20	60

sections of good clam bearing beaches should assure a continued recreational fishery regardless of increased clamming pressure. Finally, a new law which became effective late in 1951 will do much to remedy the third factor. This law states, "All undersized clams shall immediately be returned to the hole from which they are dug."

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NOTES ON THE EMBRYOLOGY AND BEHAVIOR OF THE FLYINGFISHES (*CYPSELURUS*) OFF THE COAST OF SOUTHERN AND BAJA CALIFORNIA[1]

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INTRODUCTION

Two species of the flyingfish, *Cypselurus*, have been recorded from Southern and Baja California waters. One of these as yet unnamed was separated from *Cypselurus californicus* (Cooper) by Hubbs and Kampa (1946) on the basis of structural differences in the eggs of the two species, chiefly the size of the eggs and the number and position of the filaments on the zona radiata. The eggs of *C. californicus* average 1.64 mm. in diameter and have around 60 long filaments attached uniformly over the surface of the egg, whereas the eggs of *Cypselurus* sp. average about 2.2 mm. and have two groups of filaments attached on opposite poles of the egg (Figure 1, upper).

Two specimens of *Cypselurus* sp. were brailed from under a light on board the M. V. Yellowfin on August 10, 1951, in Pyramid Cove, San Clemente Island, California. Both individuals, a male (286 mm. S. L.) and a female (283 mm. S. L.), were in spawning condition. About 500 eggs were stripped and fertilized and their development was recorded. Up to this date the only evidence of *Cypselurus* sp. spawning off the coast of Southern California has been from clusters of developing eggs found in the surf near La Jolla, California, by Barnhart (1936) and Dr. Grace Orton (personal communication, 1951).

On August 12, 1951, two days after the collection of the two specimens of *Cypselurus* sp. two spawning pairs of *Cypselurus californicus* were collected in the same manner at Santa Cruz Island, California. To compare the embryonic development of the two species under the same conditions several hundred eggs were stripped and fertilized and their development was recorded as before.

METHODS

The eggs were inseminated with milt from the male, washed clean, and placed in fresh sea water. The temperature of the water at the time of collection was 62.8 degrees F. During the next four days the water temperature varied from 62.6 degrees to 64.6 degrees F. as the vessel cruised about the coast. Whenever possible fresh sea water was added every two or three hours. A 100-watt light was constantly burning in the laboratory because of routine sardine work at hand, therefore the eggs experienced no actual darkness during their development. Hourly samples were taken from the jar and were observed under a dissecting scope

[1] Submitted for publication February, 1952.

with 3x objectives and 10x oculars. Drawings were made of the various stages of development up to the time when all the eggs were killed due to a severe biotic (probably fungus) infection.

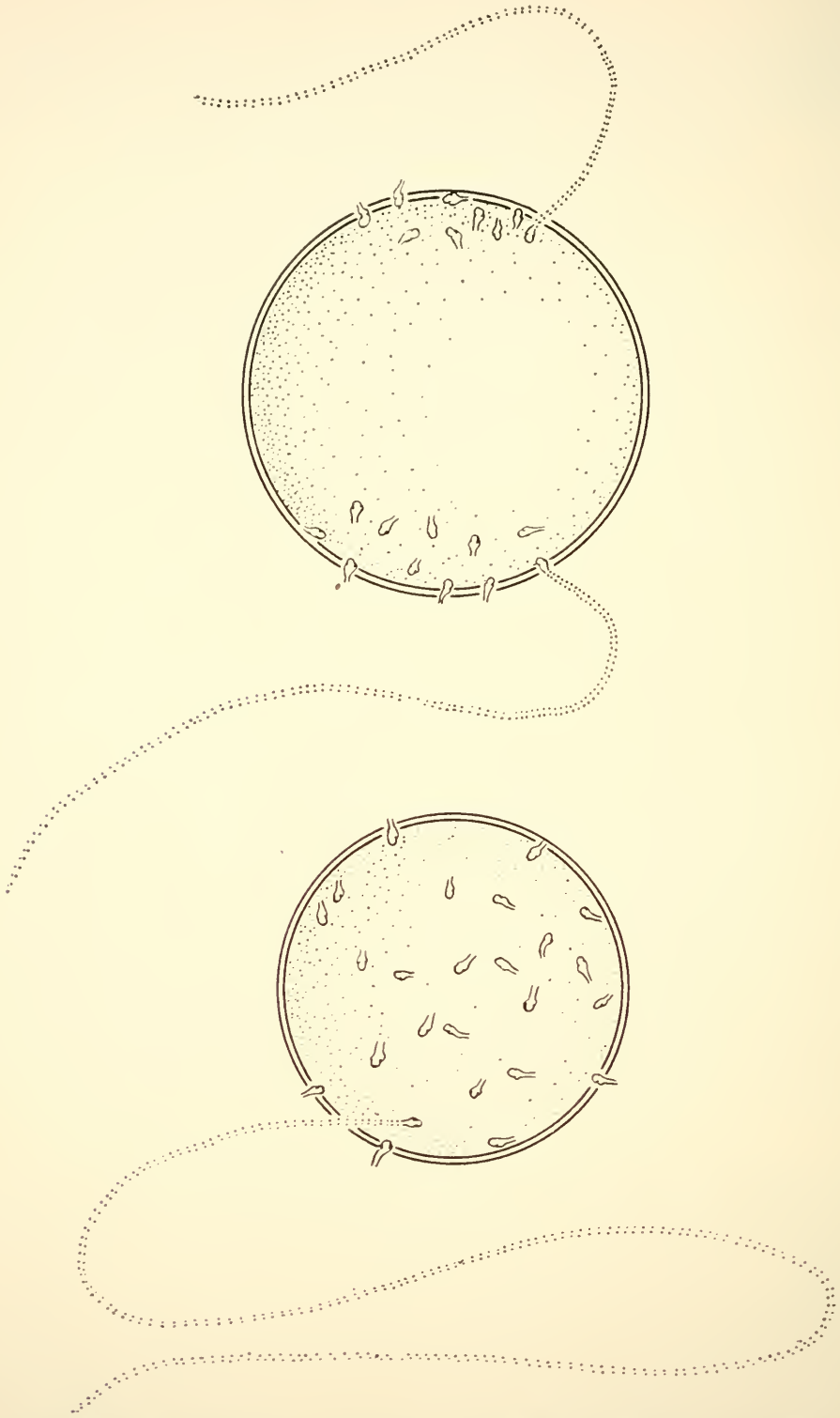

FIGURE 1. *Upper:* Egg of *Cypselurus* sp. showing the position of the filaments. Only one filament at each pole is drawn. The bases of the others are indicated. *Lower:* Egg of *Cypselurus californicus* showing one filament drawn with the bases of others.

DESCRIPTION OF THE EGGS AND "STRING" OF *CYPSELURUS* SP.

As described by Barnhart (1936) the eggs of *Cypselurus* sp. have two groups of filaments attached on opposite poles of the zona radiata. Each group of from 18-28 filaments occupies a little less than a fourth of the surface of the egg, and in most cases they are opposite each other. Hubbs and Kampa noticed that most of the filaments at one pole varied in diameter and were larger and thicker than at the other pole. The filaments of this larger group are shown in Figure 2 which illustrates the formation of a small cord by these filaments. The eggs of the specimen collected at San Clemente agree with the above except in the number

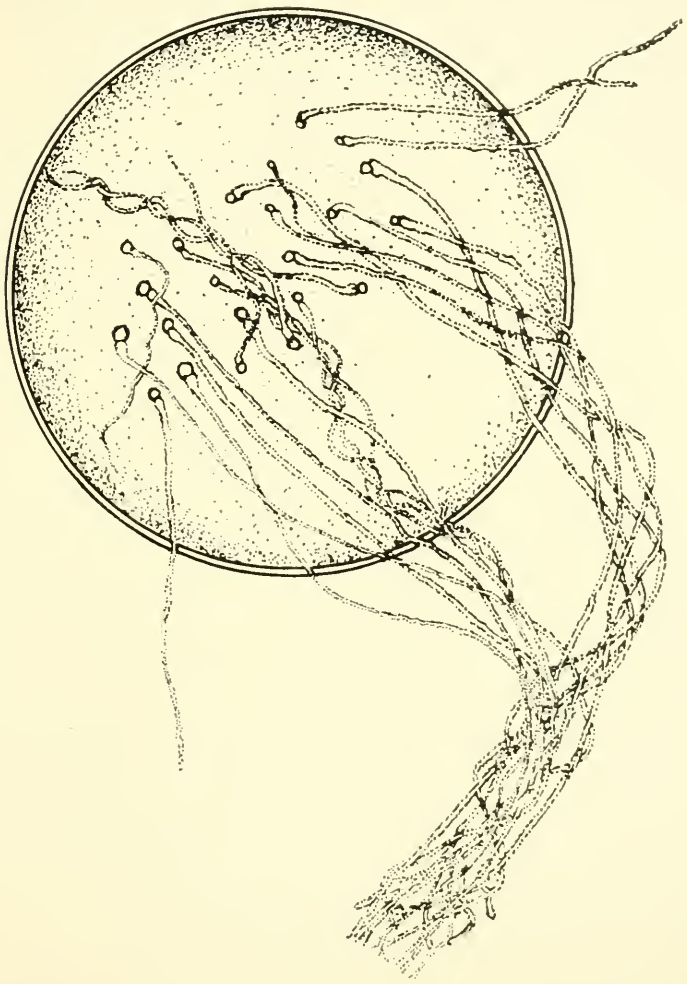

FIGURE 2. Egg of *Cypselurus* sp. showing the filaments of the larger group where a small cord is formed by these filaments.

of filaments. In most cases there was a greater number (19-32) at each pole.

In the San Clemente specimen the eggs were attached in grape-like clusters of a few to several hundred eggs in a bunch upon a surprisingly tough elastic string. These grape-like clusters of eggs are formed when filaments of several eggs join together forming small cords which then become intertwined with the filaments of the long string. These individual clusters of eggs were attached rather unevenly upon the string, sometimes with as much as 18 inches or more between them. The string

FIGURE 3. Four blastomere stage. 3½ to 4 hours after fertilization.

FIGURE 4. Four blastomere stage showing position of the blastomeres with relation to the filaments

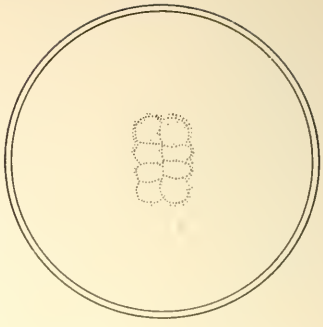

FIGURE 5. 8-cell stage. 4½ to 5 hours.

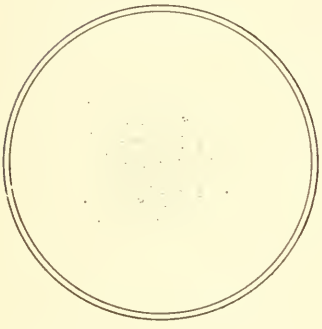

FIGURE 6. 16-cell stage. 6 hours.

FIGURE 7. Early blastodisc stage. 10 hours.

FIGURE 8. Blastodisc formed. 12 hours.

FIGURE 9. Segmentation cavity forming inside germ ring. 20 hours.

FIGURE 10. Germ ring approaching equator. 24 hours.

FIGURE 11. Germ ring at equator. Embryo forming. 30 hours.

FIGURE 12. Embryo beginning to take form. Blastopore covering ⅓ area of egg. 40 hours.

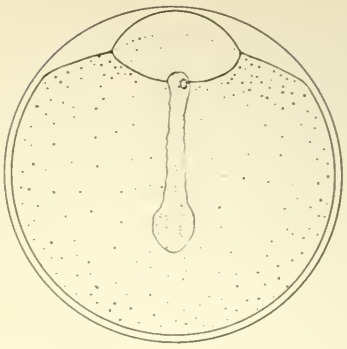

FIGURE 13. Embryo well formed. Optic lobes, neural tube, Kupffer's vesicle clear. Blastopore almost closing. 52 hours.

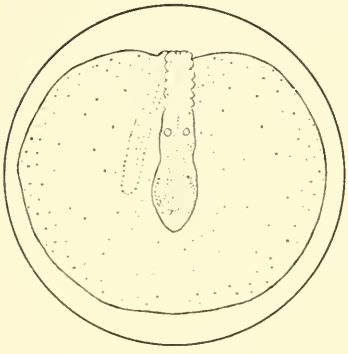

FIGURE 14. 24 somites in number. Auditory sac evident. 92 hours.

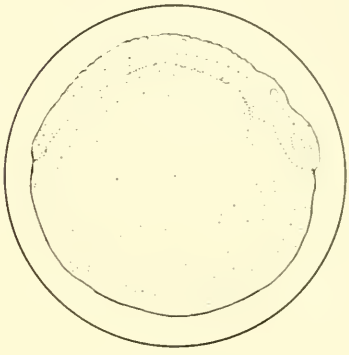

FIGURE 15. Side view of Figure 14

consisted of many fine white interwoven filaments and seemed to be of a continuous structure. When the female was extracted from the brail the string became attached to the webbing, and before the string could be severed several yards of it were drawn out of the ovarian cavity. Later, when the eggs were stripped for fertilization, several more yards of the string were drawn out until it broke off inside the body. The method of stripping was accomplished by pulling on the string and drawing out the attached clusters of eggs until none were left. The adaptive advantage of this string is shown by Beebe (1938) who found a large cluster of eggs belonging to this species wound about stems and fronds of a mass of floating kelp near Clarion Island, Mexico. This cluster consisted of two batches of eggs, each in a different stage of development.

The average diameter of 10 fertilized eggs taken from the San Clemente specimen and preserved in formalin was 2.18 mm. with a range of 2.0 to 2.4 mm. They were amber colored and spherical in shape.

DEVELOPMENT

The various stages of development are shown on Figures 3-15.

Fertilization took place at 8 p.m., and six hours later the 16-cell stage was reached. A few four-cell and several eight-cell stages were present at this time indicating a differential developmental rate of the eggs.

In all cases cell division took place immediately under the portion of the zona radiata where the smallest and thinnest group of filaments was attached (Figures 3 and 4). Also, it was the larger filaments of the group at the vegetal pole (Figure 2) that formed the small cord attaching the egg to the string.

At 10 hours after fertilization the blastomeres were beginning to form into a blastodisc. In 12 hours the blastodisc was well formed taking on a bright white color in comparison to the amber color of the zona radiata. (At this time the blastodisc started to change position with relationship to the animal and vegetal poles by migrating to a more central position between the two poles.) In 24 hours after fertilization the segmentation cavity was forming, and in 30 hours several eggs were found in which the germ ring had reached the equator. The first sign of embryo formation was noticed at 40 hours. In this specimen the length of the primitive streak was about $\frac{1}{2}$ the diameter of the egg. A Kupffer's vesicle was noticed in a 52-hour sample as well as the optic lobes and neural tube. The 24 somite stage was reached at 92 hours. The auditory sacs were evident and the embryo was curved about half way around the inside of the egg. At this time very few eggs remained alive so the entire mass was preserved in 10 percent formalin.

BRIEF EMBRYOLOGICAL COMPARISON OF THE TWO SPECIES

The most obvious difference between the eggs of the two species other than that of the filaments and size of the eggs was the fact that the eggs of *C. californicus* were released in a mass consisting of individual eggs and were not attached to a string as in *Cypselurus* sp. Several hundred eggs of *C. californicus* were fertilized, and it was found that the rate of development of the eggs of both species was almost identical under similar conditions—the various cleavage and embryonic stages appearing at approximately the same intervals of time. Four larvae of *C. californicus* were hatched on the 16th day after fertilization between the hours of 1 p.m. and 8 p.m. The eggs of both species are heavier than sea water and since the eggs of *C. californicus* are not attached to a string each egg must attach itself to floating objects by means of the numerous long filaments shown in Figure 1—lower. A complete description of the eggs of *C. californicus* is given by Hubbs and Kampa (1946).

BEHAVIOR

In both species the adults were paired during the spawning period. The pair of *Cypselurus* sp. at San Clemente remained very close to each other while they circled randomly about under the light. The female was captured first as she lay motionless just under the surface with pectorals and ventrals spread out. The male then continued swimming about in the area for 10 minutes or more until he came close enough to the surface to be brailed. The two pairs of ripe *C. californicus* were collected in the same manner and made little or no effort to escape the brail as it descended upon them. They were paired and remained close to each other as with *Cypselurus* sp. For the most part the two pairs remained separated as they came to the light, but occasionally all four

individuals would circle the light together. During these brief intervals there was no evidence of dominance or rivalry expressed between any of the individuals.

It was thought at the time that the bright light emitted by the 750-watt bulb so blinded the fish that they were unable to observe moving objects above the water. However, later observations indicated that this unwariness was true of paired ripe adults. On August 25, 1951, at Cedros Island, Baja California, Mexico, a group of *C. californicus* gathered around the light at 8:00 p.m. In all, 12 running males, one nonripe adult male and three nonripe adult females were collected. In contrast to the unwaryness of the spawning pairs mentioned before these individuals were quite alert and reacted quickly to any motion above the water. The 16 specimens were collected with difficulty and frequently the entire group was frightened away. A member of the crew observed that in the group of ripe males one of them emitted a faint white cloud of milt as he approached the surface under the light. In this case the male was actually in the act of spawning apparently with no ripe female present. Several hours later a few miles to the south a nearly ripe female *C. californicus* was killed and floated to the surface when a charge of explosives was set off under the light. Previous to the blast several *Cypselurus* were observed but they were too wary to be caught with the brail.

Hornell (1923) stated that the natives off the Coromandel Coast of India catch spawning flyingfish (*Cypselurus*) with brails as the fish gather around piles of floating brush placed in the water by the natives for the purpose of attracting them. Possibly this method is used by the natives not only because the fish are concentrated in a small area where it is easier to catch them but because the spawning fish are actually easier to brail.

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DISTRIBUTIONAL NOTES ON SOME PACIFIC COAST MARINE FISHES[1]

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Some of the fishes listed in this paper represent new distributional records, some established definite geographical collection localities and still others are taken so infrequently or are unusual enough to warrant a published record. Most of the specimens were collected by various biologists and crew members aboard the two Department of Fish and Game research vessels YELLOWFIN and N. B. SCOFIELD. A table of latitudes and longitudes has been included for all collecting localities.

Scoliodon longuria (Jordan and Gilbert)—sharpnose shark

A single sharpnose shark 301 mm. long was taken in a 160 foot beach seine near Long Beach, California, on July 28, 1951, by Mr. D. C. Joseph and party. This, the second California record of *Scoliodon longurio*, is presented through the courtesy of Dr. Boyd W. Walker, University of California, Los Angeles who has the specimen listed in his field notebook, W 51-127.

Carcharhinus velox Gilbert

The eighth known *Carcharhinus velox* was taken in a trammel net by the YELLOWFIN on April 16, 1950. The net had been set over night in five fathoms of water just off Belchers Point, Magdalena Bay, Baja California. This extends the known range for this shark north somewhat over 150 miles from Cape San Lucas.

Squatina californica Ayres—angel shark

Several angel sharks were taken in trammel and gill nets along the Baja California coast by the YELLOWFIN in 1950. Localities and dates are: Ballenas Bay, one in 10-inch trammel net April 11; San Juanico Bay, two in two-inch-mesh gill net April 13; Belchers Point, Magdalena Bay, two in 10-inch trammel net April 16; Horseshoe Shoals, Magdalena Bay, five in 10-inch trammel net April 17. These collections extend the known range for this species south of the general limit, "northern Baja California," usually given.

Platyrhinoidis triseriata (Jordan and Gilbert)—thornback

Capture of a thornback on hook and line at Santa Rosalia Bay, Baja California, on April 6, 1950, by the YELLOWFIN extends the known range south from San Quintin Bay, a distance of about 150 miles.

Narcine entemedor Jordan and Starks—electric ray

A single specimen was taken in a beach seine at San Juanico Bay, Baja California, by the YELLOWFIN on August 31, 1951. This collection

[1] Submitted for publication May, 1952.

adds to the spotty distribution records for this species on the outer coast of Baja California.

Albula vulpes (Linnaeus)—bonefish

A number of bonefish taken in Southern California waters between November 19, 1951, and May 31, 1952, were reported to the California State Fisheries Laboratory, Terminal Island. One was caught on hook and line at Santa Barbara on December 9, 1951, the remainder were reported from the Los Angeles Harbor area.

Anchoa ischana (Jordan and Gilbert)—anchovy

A number of these anchovies were collected in Magdalena Bay, Baja California, by the YELLOWFIN during 1952. These included: two from a beach seine haul at Turtle Inlet on March 26; five with explosives near shore at Yellow Bluff on March 27 and 41 under a light 1.5 miles south of Yellow Bluff on the night of March 27. Magdalena Bay is reported as the northern limit of the range for this species on the outer coast of Baja California.

Lampris regius (Bonnaterre)—opah

A 57-pound opah was caught on September 15, 1951, by Mr. Robert Clarke of Westminster, California, some 10 to 12 miles off Newport Beach. The flesh of this fish was considered of excellent flavor both fresh and smoked.

Trachipterus rexsalmonorum Jordan and Gilbert—ribbonfish

Two ribbonfish were brought to the California State Fisheries Laboratory on October 21, 1951, by Mr. Ben Fukuzaki, skipper of the seiner NANCY ROSE. These fish, 16½ and 22 inches in length, were caught in a purse seine the previous night some eight or nine miles off Newport Beach in 35 fathoms of water.

Lophotus sp.—crestfish

In the early part of August, 1951, one of these interesting fishes was seen swimming feebly in the surf at Avalon, Santa Catalina Island, California, and picked up by Edward Huffaker of San Pedro. This crestfish, fourth known from the Pacific Coast, was destroyed and the identification is from photographs.

Leuresthes tenuis (Ayres)—grunion

Six grunion were collected under a light at San Juanico Bay, Baja California on April 12, 1950, by the YELLOWFIN. The present record is published to establish a possible southern distribution limit for the species.

Nematistius pectoralis Gill—roosterfish

The collection of one young *Nematistius pectoralis* at Turtle Bay, Baja California, on August 28, 1951, and 20 at Asuncion Point, Baja California, on August 29, 1951, by the YELLOWFIN establishes its presence on the outer coast of Baja California.

Palometa snyderi (Gilbert and Starks)

Three of these fish were caught on snag hooks by the author from the YELLOWFIN while at anchorage in San Juanico Bay, Baja California, during the night of April 12, 1950. Occurrence of this species at San Juanico extends the range north from Panama Bay.

Icichthys lockingtoni Jordan and Gilbert (Figure 1)

On October 15, 1950, a large purple striped jellyfish was dipped from the YELLOWFIN and found to have one of these fish living commensally within the gastrovascular cavity of the jellyfish. Locality of capture was about 60 miles off Pt. Buchon, California (lat. 35°34′N, long. 122°20′W.). On May 22, 1951, a second specimen 42.4 mm. standard length, was dipped from under a light by the N. B. SCOFIELD while at anchorage at San Nicolas Island, California. Finally on May 10, 1952, two specimens 83 and 108.5 mm. standard length, were taken in a bait net just inside the Santa Monica breakwater. These latter two fish (Figure 1) show several changes in body outline from those younger stages which live commensally with jellyfish, but still bear little resemblance to the adult.

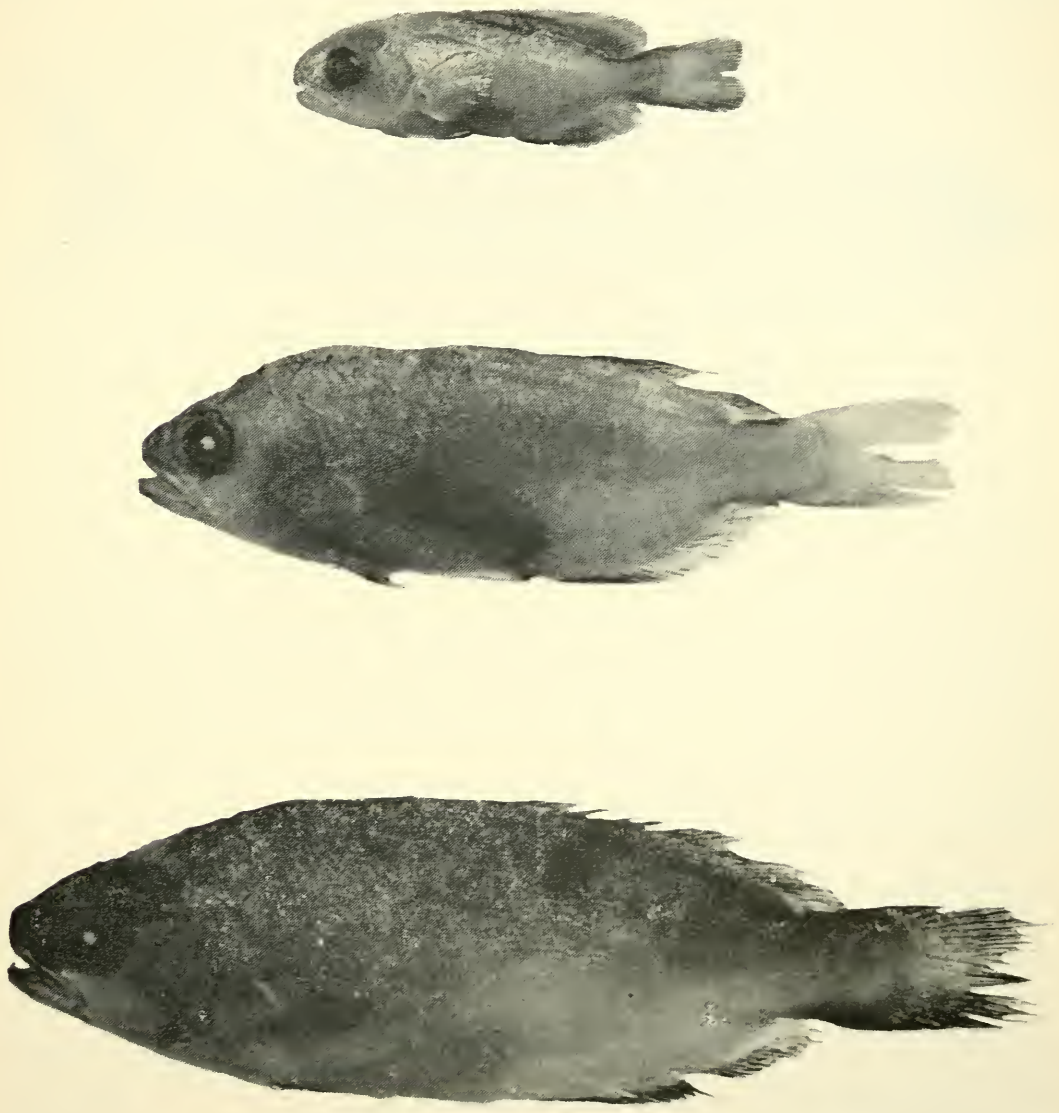

FIGURE 1. Three stages in the development of *Icichthys lockingtoni*. Top specimen was found living commensally within the gastrovascular cavity of a jellyfish; center and lower specimens show transformation stages. *Center and lower photographs by Herb Phillips, San Pedro.*

Pneumatophorus diego (Ayres)—Pacific mackerel

On April 5, 1950, Mr. Ben Fukuzaki, skipper of the seiner NANCY ROSE dipped a small Pacific mackerel from under a light while drifting on the 450 fathom bank some 60 miles west of Mazatlan, Mexico. Pacific mackerel have previously been reported along the Baja California coast to Cape San Lucas and into the Gulf of California; however, this is the first record from the mainland side of the Gulf.

Scomberomorus concolor (Lockinton)—Monterey Spanish mackerel

A Monterey Spanish mackerel was taken with a bait net in the Los Angeles Harbor during October, 1951. This species has been reported from California waters almost annually for the past decade. It has been found to be extremely abundant in the northern part of the Gulf of California.

FIGURE 2. Black skipjack, *Euthynnus lineatus*. Photograph by Al Johns for Vernon M. Haden, San Pedro

Euthynnus lineatus Kishinouye—black skipjack (Figure 2)

On July 21, 1951 a black skipjack 412 mm. fork length was taken off Dana Point, California by Mr. Steve Licato of Pomona while fishing from the sportfishing boat SEA BISCUIT. This is the second California record for this southern form; the first, in July 1939, was from Santa Barbara Island.

Lutianus novemfasciatus (Gill)—dog snapper
Lutianus argentiventris (Peters)—yellowtail snapper
Lutianus colorado (Jordan and Gilbert)—Colorado snapper
Lutianus aratus (Gunther)—mullet snapper

Collection of these four species of snappers by the YELLOWFIN in Santa Maria Lagoon, Baja California on April 14, 1950, establishes their presence on the outer coast of Baja California. This collection, taken with poison, includes one each of dog and mullet snappers, three Colorado snappers and ten yellowtail snappers, all of which were adults. A single young yellowtail snapper was taken with poison in the same lagoon by the YELLOWFIN on March 28, 1952.

Isopisthus remifer Jordan and Gilbert

Seven adult *Isopisthus remifer* were taken in two-inch-mesh gill nets by the YELLOWFIN on April 13, 1950, at San Juanico Bay, Baja California. On the night of August 30, 1951, four juveniles of this species were dipped from under a light at Abreojos anchorage, Baja California. These records establish this species on the outer coast of Baja California.

Cynoscion reticulatus (Gunther)—striped corbina

Four striped corbina were taken in gill nets on the outer coast of Baja California by the YELLOWFIN in March 1952. One was caught March 27, 1.5 miles south of Yellow Bluff, Magdalena Bay and the remaining three on March 28, 0.7 mile northeast of Smart Peak, Santa Maria Bay. These fish are relatively common in the Gulf of California but this is believed to be the first record from the outer coast.

Roncador stearnsi (Steindachner)—spotfin croaker

Over 250 spotfin croaker up to 15 inches in length were taken in gill nets by the YELLOWFIN at San Juanico Bay, Baja California on April 13, 1950. These represent a considerable southward extension of the known range, which is usually given as extending to central Baja California.

Genyonemus lineatus (Ayres)—kingfish

Collection of 18 kingfish in gill nets at San Juanico Bay, Baja California on April 13, 1950, extends the range for this species southward from "central Baja California."

Seriphus politus Ayres—queenfish

On April 13, 1950, 43 queenfish were taken in some two-inch-mesh gill nets by the YELLOWFIN. These nets had been set overnight in five fathoms of water at San Juanico Bay, Baja California. Collection of these fish at this locality extends the known range for this species southward from central Baja California.

Menticirrhus panamensis (Steindachner)—Panama corbina

An adult Panama corbina was taken in a beach seine on March 26, 1952, at Turtle Inlet, Magdalena Bay, Baja California by the YELLOWFIN. This is the first record of this species from the outer coast of Baja California.

Embiotoca jacksoni Agassiz—black perch

Five large black perch were collected just inside Abreojos Point, Baja California by the YELLOWFIN on April 11, 1950. This extends the known range for this species south from the San Benitos Islands, a distance of about 150 miles.

Brachyistius frenatus (Gill)—kelp perch

Four adult kelp perch were collected just outside the entrance to Turtle Bay, Baja California by the YELLOWFIN on April 8, 1950. This extends the known range for kelp perch south from Todos Santos Island, a distance of about 270 miles.

Pomacentrus rectifraenum (Gill)

On April 13, 1950, a small *Pomacentrus rectifraenum* was collected in a tide pool at San Juanico, Baja California by the author. On March 25, 1952, 34 of this species were taken in tide pools at Point Pequeña, San Juanico, Baja California by the YELLOWFIN. This southern form has been previously reported from the outer coast of Baja California on but one occasion (Brock, 1938).

Abudefduf saxatilis (Linnaeus)

Four adult *Abudefduf saxatilis* were taken from tide pools at Point Pequeña, San Juanico by the YELLOWFIN on March 25, 1952. This extends the range northward on the outer coast of Baja California a distance of over 200 miles.

Pomacanthus zonipectus (Gill)—butterflyfish

A single butterflyfish of this species was taken from a tide pool at Point Pequeña, San Juanico by the YELLOWFIN on March 25, 1952. *Pomacanthus zonipectus* had previously been reported from the outer coast of Baja California on but one occasion (Brock, 1938).

Sebastodes miniatus (Jordan and Gilbert)—vermilion rockfish
Sebastodes carnatus (Jordan and Gilbert)
Sebastodes vexillaris (Jordan and Gilbert)
Sebastodes serranoides Eigenmann and Eigenmann
Sebastodes gilberti Cramer

On September 26, 1951, these five species of rockfish were caught on hook and line by the YELLOWFIN 0.6 miles southwest of Point San Jose, Baja California, in 55 feet of water. Since the southern limit of the range for these species is listed as "Southern California" the present records establish their presence in Baja California, nearly 75 miles south of the Mexican border. All identifications were made by Mr. J. B. Phillips, Bureau of Marine Fisheries, Pacific Grove, California.

Aulorhynchus flavidus Gill—tube snout (Figure 3)

FIGURE 3. Tube snout, *Aulorhynchus flavidus*. *Photograph by Al Johns for Haden and Carpenter, San Pedro.*

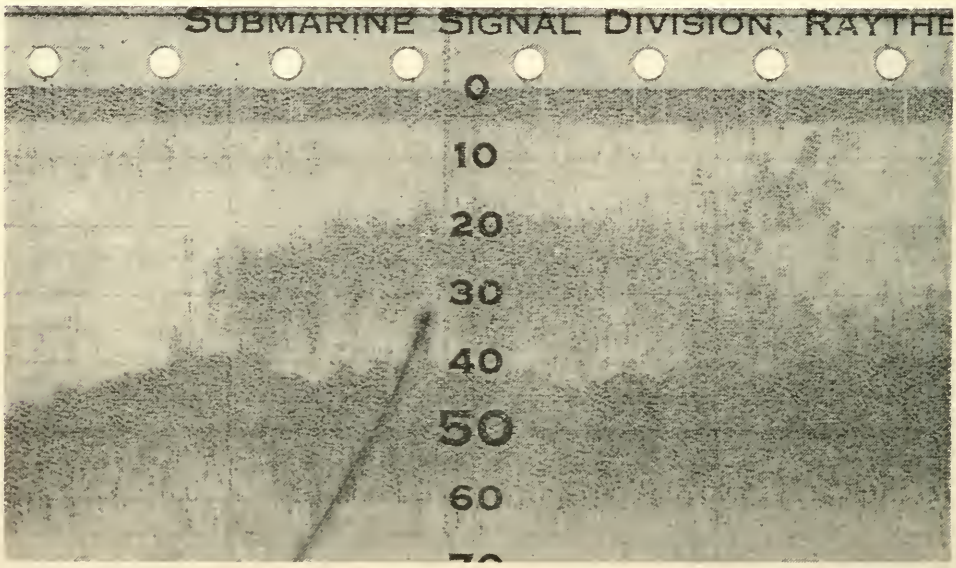

FIGURE 4. Trace on fathogram showing school of tube snouts off Santa Rosa Island. To obtain correct depth in feet multiply numbers by two. The bottom is indicated by the dark trace which crosses the chart at about the 80-foot level. The dark line running from the bottom of the fathogram to near the 30 mark is a pencil mark indicating a collecting station number for the *Yellowfin*.

On the night of November 16, 1950, a very large and dense school of these fish was encountered by the YELLOWFIN in 80 feet of water some three miles southwest of South Point, Santa Rosa Island, California. These fish were at a depth of 30 to 70 feet and the diameter of the school was estimated at nearly one-fourth mile. Tube snouts usually occur in small groups closely associated with kelp beds along shore from La Jolla to southeastern Alaska. A single specimen taken at Point Banda, Baja California, on March 28, 1948, by the N. B. SCOFIELD extends the known range south by nearly 75 miles.

Remicola eigenmanni (Gilbert) clingfish

Briggs (1951) gives the range for this species as Todos Santos Bay, Baja California, to the west coast of Vancouver Island, British Columbia. Collection of an adult *Remicola eigenmanni* from a large piece of kelp caught in a trammel net 1½ miles west of Arroyo Mesquital, San Juanico, Baja California, constitutes a southward extension of the range by more than 400 miles. The trammel net had been set in eight fathoms over the night of April 12, 1950, by the YELLOWFIN.

Heterostichus rostratus Girard—kelpfish

On April 13, 1950, a young kelpfish was found in some kelp entangled in a trammel net which had been set in eight fathoms of water 1½ miles west of Arroyo Mesquital, San Juanico, Baja California, by the YELLOWFIN. Hubbs (1952) states that this species has been taken as far south as Cape San Lucas but is not common south of Ballenas Bay, Baja California. The present specimen establishes a collecting locality between these two points.

Verrunculus polylepis (Steindachner)—triggerfish

A considerable number of these triggerfish ranging from 10 to 15 inches in length were caught by sport fishermen from the Redondo Beach, California, pier during the summer of 1951. Six of those taken during July were sent to the California State Fisheries Laboratory for identification.

Lactoria diaphana (Bloch and Schneider)—boxfish

Many of these boxfish were caught by purse seiners during the fall of 1951. All of the specimens sent to the California State Fisheries Laboratory were taken within a few miles of Los Angeles Harbor and ranged from two to seven inches in total length. Dates of capture are: September 5 (1 fish); October 3 (2 fish); and November 5 (2 fish). Several others were reported for which no data are available.

TABLE 1

Latitude and Longitude of Places Mentioned in the Text

Locality	Latitude	Longitude
California		
Santa Barbara	34° 25′	119° 41′
Santa Rosa Island	33° 55′	120° 00′
Redondo Beach	33° 53′	118° 26′
Long Beach	33° 46′	118° 13′
Newport Beach	33° 38′	117° 54′
Dana Point	33° 27	117° 42′
Avalon, Santa Catalina Island	33° 21′	118° 19′
San Nicolas Island	33° 16′	119° 30′
Baja California		
Point Banda, Todos Santos Bay	31° 51′	116° 38′
Point San Jose	31° 27′	116° 37′
Santa Rosalia Bay	28° 40′	114° 14′
Turtle Bay	27° 40′	114° 52′
Asuncion Bay	27° 09′	114° 15′
Abreojos Point, Ballenas Bay	26° 45′	113° 30′
San Juanico Bay	26° 15′	112° 28′
Santa Maria Bay	24° 47′	112° 16′
Magdalena Bay		
Turtle Inlet	24° 44.0′	111° 56.5′
Yellow Bluff	24° 43.1′	111° 58.8′
Belchers Point	24° 37′	112° 07′
450-Fathom Bank	23° 05′	107° 33′
Cape San Lucas	22° 52′	109° 53′

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THE FANFISH, *PTERACLIS VELIFERA*, FOUND IN CALIFORNIA[1]

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CHARLES O. BLODGETT
San Luis Obispo High School and Junior College

Although the fanfish, *Pteraclis velifera* (Pallas) has been known for a long time in Atlantic waters and in the seas around Japan and Africa, it has never before been reported from the U. S. Pacific coast. Even in other localities this fish is rare.

Toward the latter part of September, 1951, a fisherman was surf casting for perch on the beach just south of the mouth of Santa Rosa Creek near Cambria in northern San Luis Obispo County, California. The day was warm and clear and the water was relatively calm. The fisherman baited a No. 4 hook with a small sand crab (*Emerita analoga*) and cast into the moderate surf. He soon noted that he had caught what he believed to be a perch. The fish put up practically no fight while being drawn in. The man grasped the animal and found, "silvery stuff like aluminum paint" coming off on his hand. He then discovered huge, membranous dorsal and anal fins which had been completely hidden in longitudinal dorsal and ventral grooves.

The specimen was brought by the fisherman's nephew a day or two later to the junior author for identification. The senior author was consulted and finally a description was sent to Dr. Carl L. Hubbs of Scripps Institution of Oceanography who identified it as *Pteraclis velifera*. In the meantime the fish was prepared as a taxidermy mount. This mount has been sent to Scripps Institution of Oceanography, La Jolla, California.

Pteraclis velifera was described as a new genus by Jordan and Snyder (1901) under the name *Bentenia aesticola*. They distinguished it from *P. velifera* on the basis of a spine in the dorsal fin and a spine in the anal fin and placed it in the family Pteraclidae. More recently *B. aesticola* has been synonymized with *P. velifera* by Smith (1949). Because of intermediate types, Berg (1947) has placed it in the family Bramidae. For a detailed description of the species see Jordan and Snyder (1901) and Smith (1949).

A brief description of the California specimen follows. Total length 51 cm.; tip of head to posterior margin of operculum 8 cm.; depth of head, through eye, 8 cm.; length of caudal fin 7 cm.; pectoral fin (dried) 8 x 1.5 cm.; diameter of eye 2 cm.; margin of dorsal fin can be lifted 26 cm. from body; margin of anal fin can be pulled 20 cm. from body; dorsal and anal fins fit into longitudinal grooves 1-2 cm. deep formed by modified scales; body laterally compressed, 1.9 cm. through center,

[1] Submitted for publication February, 1952.

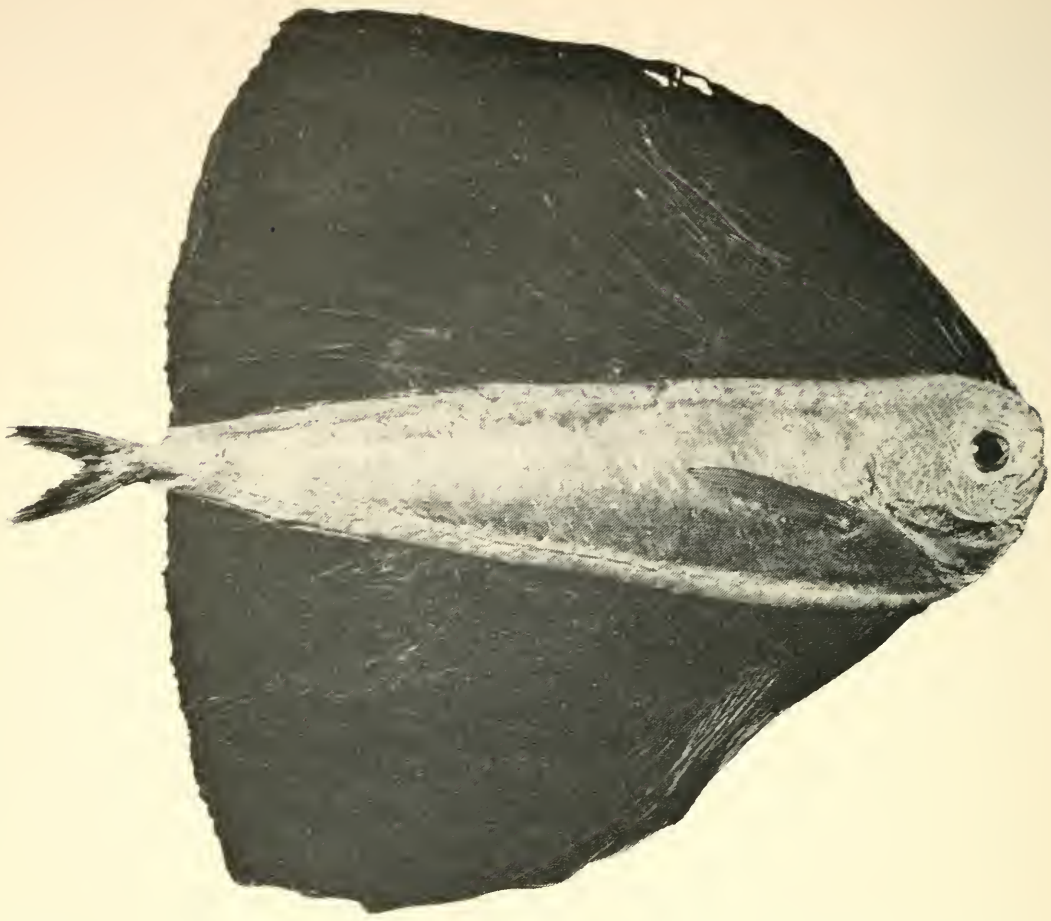

FIGURE 1. Fanfish, *Pteraclis velifera*. Photograph of the mounted specimen courtesy of Scripps Institution of Oceanography, La Jolla, California.

1.3 cm. through area just anterior to caudal fin, 3.4 cm. through area of operculum; scales variable, many with centrally placed spine; scales hard and fitting tightly against body; mouth and margin of operculum almost indistinguishable in fresh specimen; mouth appears almost vertical from a lateral view; iris pale orange-red; body cavity extremely short, limited to anterior quarter of body; body bright silvery; dorsal and anal fin membranes, thin, delicate and jet black (possibly colored in living specimen); dorsal and anal fin rays progressively smaller from anterior to posterior becoming long, slender and thread-like, about 34 in the dorsal fin and 32 in the ventral fin; double row of teeth in both jaws, about 24 teeth in one row in each half of a jaw; occasional teeth between the two rows.

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VARIATIONS IN THE WOLF EEL, *ANARRHICHTHYS OCELLATUS* AYRES, A FISH INHABITING THE EASTERN NORTH PACIFIC OCEAN[1]

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Division of Fishes, U. S. National Museum, Washington, D. C.

INTRODUCTION

Preliminary examination of United States National Museum specimens of *Anarrhichthys ocellatus* Ayres indicated the possibility of two forms, for differences were noted in color pattern, dentition and body proportions. A study of 37 specimens, ranging in length from 175 to 1,693 mm. revealed that these differences were variations of a single species; therefore, it seems pertinent to give a redescription of the species.

FAMILY ANARHICHADIDAE

Anarrhichthys is distinguished from other genera of the family by its excessively elongate, tapering, eel-shaped body; the dorsal and anal fins are confluent with the elongate tapering caudal fin; and a greater number of vertebrae.

ANARRHICHTHYS OCELLATUS AYRES

Figures 1-3

Anarrhichas felis Girard (nomen nudum), 1854, Proc. Acad. Nat. Sci. Phila., vol. 7, p. 150-151.

Anarrhichthys ocellatus Ayres, 1855, Proc. Calif. Acad. Nat. Sci., vol. 1, p. 31-32, (type locality, San Francisco Bay, California).

Anarrhichthys felis Girard, 1858, U. S. Pac. R. R. Surv., vol. 10, Fish, p. 125-126, pl. 25a, figs. 1-3.

Specimens Studied. U. S. N. M. nos. 104500 Thorn Arm, Alaska; 103532 Hawk Inlet, Alaska; 104501 Zaikof Bay, Alaska; 57832 Knik, Alaska; 104502 Wrangell, Alaska; 55638 Seattle, Washington; 22264 Washington; 133946 Vancouver Island, British Columbia; 27149, two specimens, San Francisco, California; 511, two specimens, San Francisco, California; 10451 Farallone Island, California; 26507 Monterey, California; 27054 Monterey, California; U. W. nos. 5207, two specimens, Cape Lynch, Alaska; 5336, two specimens, Prince of Wale's Island, Point Webster, Alaska; 3781, Orca Inlet, Alaska; 2676 Uyak Bay, Kodiak Island, Alaska; 2872 Petersburg, Alaska; 6229 Hansville, Washington; 4746 three specimens, Cape Flattery, Washington; 265 Puget Sound, Washington; 1330 False Bay, Washington; 4459 Orcas Island, Washington, S. N. H. M. nos. 6065 San Francisco Bay, California; 26014 San Pablo Bay, California; 14917 Fort Ross, California; 2768 two specimens,

[1] Submitted for publication May, 1952. Published by permission of the Secretary of the Smithsonian Institution.

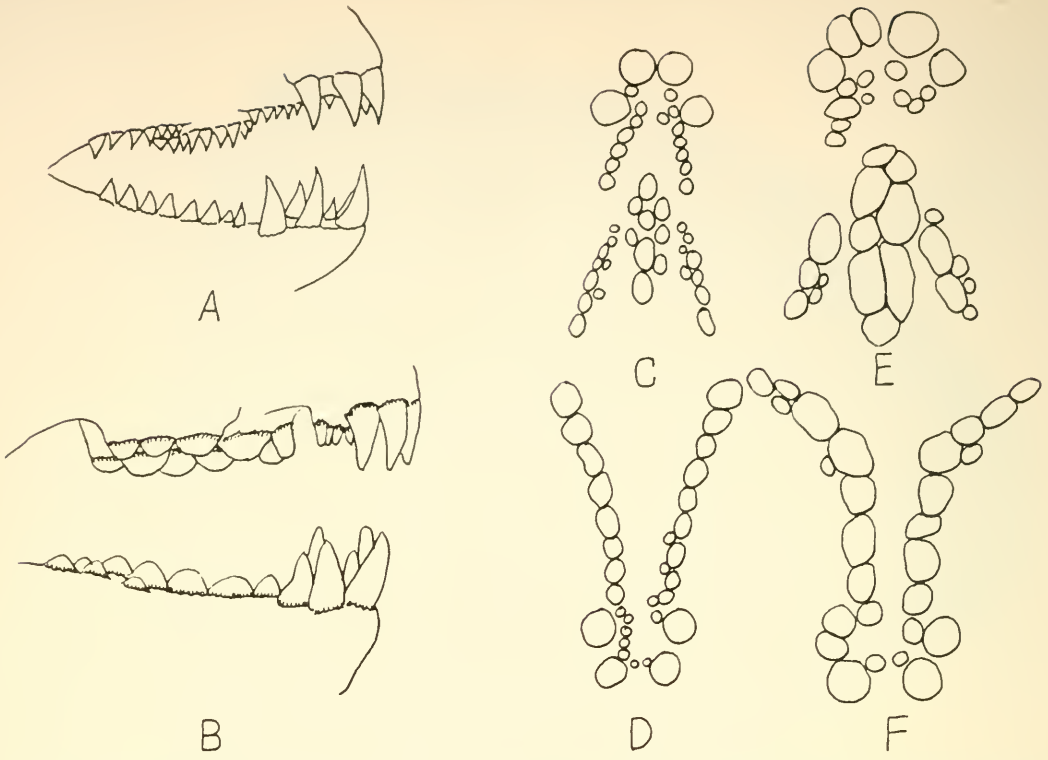

FIGURE 1. Dentition of a juvenile, two times natural size: A, lateral view; C, ventral view of upper jaw; D, dorsal view of lower jaw. Dentition of an adult, one-half natural size: B, lateral view; E, ventral view of upper jaw; F, dorsal view of lower jaw.

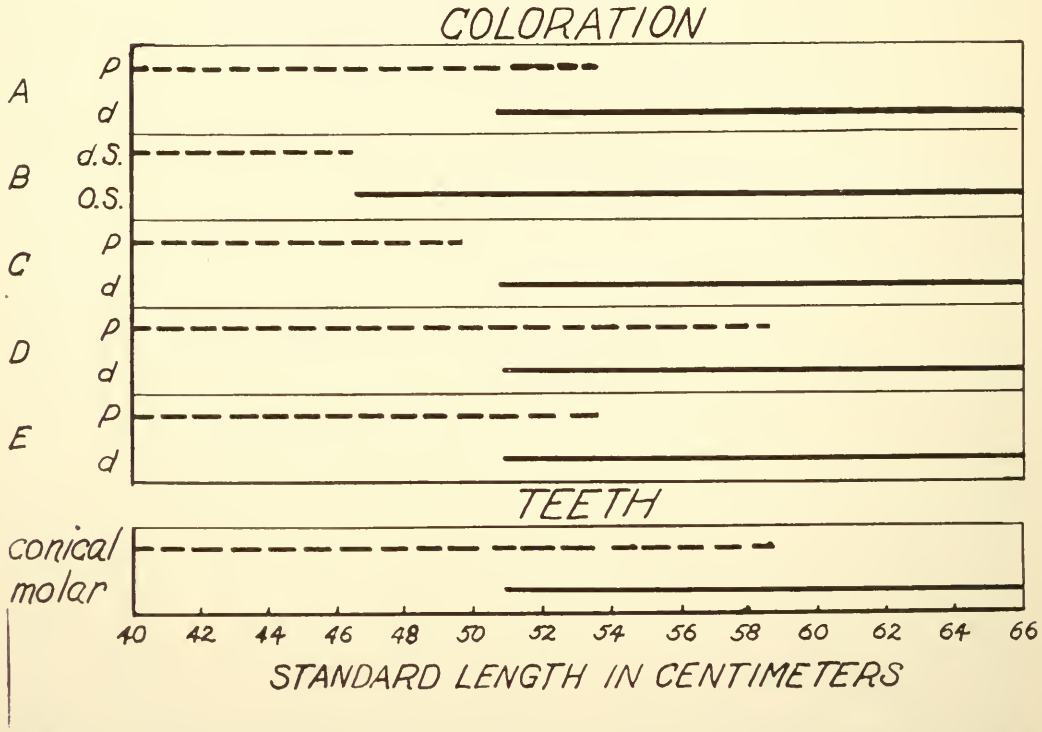

FIGURE 2. Diagram showing the sizes at which various characters transform from juveniles to adults. The broken line represents the juvenile condition and solid line that of the adults. A, pectoral fin; B, dorsal fin; C, anal fin; D, lower one-third of trunk; E, lower one-third of caudal region; p, pale; d, dusky; d.s., dusky spots; o.s., ocellated spots. The coloration of pectorals considered pale when most of the fin was pale. The coloration of dorsal fin considered with ocellated spots when the ocellation was very distinct and the paleness not very apparent in the interspaces between the dusky spots. The lower one-third of trunk and caudal considered pale when over half was pale.

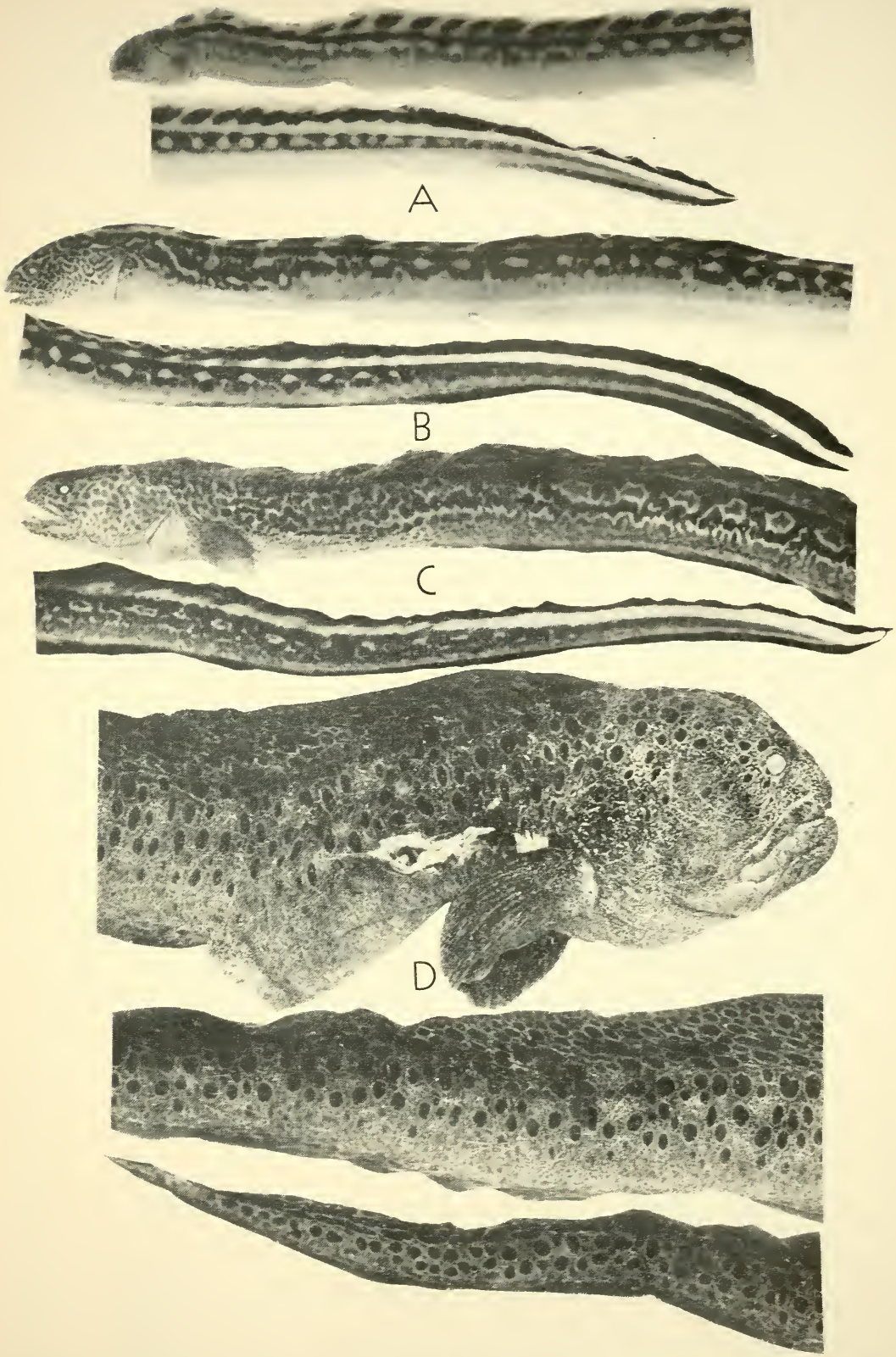

FIGURE 3. A, juvenile, 315 mm. in standard length, U. W. no. 5207, taken at Cape Lynch, Alaska; B, juvenile, 483 mm. in standard length, U. W. no. 6227, taken at Hansville, Puget Sound, Washington; C, juvenile, 586 mm. in standard length, U. S. N. M. no. 57832, taken at Knik, Cook Inlet, Alaska; D, adult, 1,405 mm. in standard length, S. N. H. M. no. 14328, taken near Monterey Highlands, Monterey County, California. *Photographs by Photographic Laboratory, Smithsonian Institution, Washington, D. C.*

TABLE 1

Measurements of Certain Characters Expressed in Thousands of the Standard Length of Anarrichthys ocellatus

Characters		Standard length in millimeters														
		200 to 299	300 to 399	400 to 499	500 to 599	600 to 699	700 to 799	800 to 899	900 to 999	1,000 to 1,099	1,100 to 1,199	1,200 to 1,299	1,300 to 1,399	1,400 to 1,499	1,500 to 1,599	1,600 to 1,699
Distance from tip of snout to origin of dorsal fin	50– 59	1	1	4	1											
	60– 69		3	2	5	1									1	
	70– 79				1			1			1			1	2	1
	80– 89											1		1	3	
	90– 99															1
	100–109												1	1		
Distance from tip of snout to origin of anal fin	170–179	1	1	1												
	180–189		2	2												
	190–199		1	3												
	200–209				2											
	210–219				4	1										
	220–229							1			1					
	230–239				1									1	1	1
	240–249															
	250–259													1	1	
	260–269														2	1
	270–279											1	1		1	
	280–289														1	
	290–299													1		
Length of pectoral fin	30– 39	1		1												
	40– 49		4	4	3											
	50– 59				3	1		1						1		
	60– 69				1						1			1	3	1
	70– 79											1	1		2	
	80– 89													1	1	1

Length of head (tip of snout to upper edge of gill opening)	60-69	1	2	1												
	70-79		2	5	3											
	80-89				4	1		1			1			1	1	
	90-99											1		1	3	1
	100-109														2	
	110-119												1	1		1
Length of upper jaw (tip of snout to rictus)	20-29	1	3	6	1										1	
	30-39		1		6	1		1			1			2	3	1
	40-49											1		1	2	1
	50-59												1			
Length of snout	12-15.9		1	3	1											
	16-19.9	1	3	3	6	1		1								
	20-23.9										1	1		1	2	
	24-27.9													1	2	1
	28-31.9												1	1	2	1
Least fleshy width of interorbital space	6-8.9	1			1											
	9-11.9		2	3	5	1										
	12-14.9		2	3				1			1	1		1	2	
	15-17.9														3	
	18-20.9												1	2	1	1
	21-23.9															1
Length of gill opening	10-19	1														
	20-29		3	4	1											
	30-39		1	2	4	1										
	40-49							1						1	1	
	50-59										1		1	1	3	2
	60-69											1		1		
Greatest depth of body	40-49	1	3	6	4											
	50-59		1		3	1										
	60-69							1								
	70-79										1			1	3	1
	80-89											1	1	1	2	
	90-99														1	1
	100-109													1		

San Francisco market, California; 9983 Eureka, California; 14328 Monterey County, California; 13367 San Francisco, California.

Distribution. Eastern Pacific ocean, recorded from off the coast of San Diego, California (Hubbs and Barnhart, 1944) to Prince William Sound and Kodiak Island, Alaska; and taken from the surface to a depth 400 feet (Hubbs & Barnhart, 1944), occasionally left on shore with falling tide.

Description. The following counts were taken from 11 specimens: dorsal spines 228-249, (230-250 Clemens and Wilby, 1946); anal rays 200-213, (200-233 Clemens and Wilby, 1946); pectoral rays 20. One skeleton has seven branchiostegals; vertebrae 247 (37 precaudal and 210 caudal); and the upper pharyngeal teeth are in three patches on each side, on lower, a long narrow patch on last gill arch on each side.

Body form much elongated, eel-shaped, compressed; greatest depth at origin of dorsal fin; head compressed, its upper surface regularly convex from occiput to extremity of snout. There is a great change in body proportion as the wolf eel grows. Measurements on nine of these characters on head and body are recorded in Table 1, expressed in thousandths of standard length. The diameter of eye did not show any increase in proportion to standard length; however, it did show a decrease in relation to the length of head. The great size of the eye is quite noticeable in very young specimens. There is a slight swelling of the nape and thickening of the lower jaw in some large specimens, whereas on others they are regularly convex and without this thickening. These may be sexual dimorphic characters; however, more specimens are needed for clarification.

Teeth in jaws very strong; 4 to 6 canine teeth at anterior end of both jaws, interlocking as the mouth is closed; tips of canines sometimes worn flattish in older specimens; noncanine teeth of jaws, vomerine and palatines are conical in juveniles (Figure 1a) whereas those of the adults are molariform (Figure 1b); in the juveniles, vomerine teeth in three rows, middle row longest (Figure 1c); palatine teeth generally in a single row; in adults 6 to 14 vomerine teeth, arranged in 2 rows (Figure 1e); palatine teeth usually in two rows. There are generally more vomerine teeth in specimens taken from Washington northward as compared with those taken from California. A remarkable transition in dentition occurs from juveniles to adults, at lengths from about 500 to 600 mm. (Figure 2). This change appears at greater sizes in specimens taken from colder Alaskan waters, and in smaller specimens from warmer Californian waters.

Color in Alcohol. There are two distinct color phases in the wolf eel; the light color phase of the juveniles and the dark color phase of the adults, see Figure 3. This transition from juvenile to adult coloration begins at sizes from 450 to 600 mm. in standard length, and correlates closely with change in dentition (Figure 2). Sizes longer than 600 mm. are considered to have adult characters, although this transition may have occurred in some individuals as short as about 500 mm. in southern waters.

The following differences in color pattern between juveniles and adults were observed: The pectoral fins are completely pale in the juvenile and as the wolf eel grows, dusky spots appear at the base of the pectoral fin

and gradually cover the whole fin. In adults the pectoral fins are dusky in color with small ocellated spots. The dorsal fin of the young is pale with a dusky stripe from posterior tip of fin forward along middle of fin. The anterior part of the stripe breaks up into large dusky spots as the wolf eel increases in size. In very young specimens the anterior parts of dorsal fins are completely pale; the dusky spots gradually progress forward with increase in body size to form a single row. As the dusky bar gets shorter the number of dusky spots increase, later faint traces of dusky pigments appear around the dusky spots to form the ocellation. As the wolf eels grow the pale basic color of the juvenile becomes dusky in color with a single row of ocellated spots along middle of the fin. Later dusky ocellated spots appear in between the large ocellated spots and form a ring around these spots; in larger specimens these spots increase in size, but not the large center spots. In older adults the spots on dorsal fin cover the fin irregularly. The dusky bar seems to persist at posterior end of the dorsal fin in older adults. The anal fin of the juvenile is pale with a short dusky bar from posterior end of fin; later a few dusky spots appear. In adults the color of anal fin changes to dusky, then to black.

The heads of juveniles are pale with dusky mottled spots on the side. These spots gradually change into ocellated spots of irregular size in the intermediate forms, and in the large adults the ocellated spots are scattered on a dusky background. The dorsal region of head and chin are pale in juveniles, later dusky spots appear on anterior part of chin, progressing posteriorly as the wolf eel grows; the black mottling encrouches on the top of the head.

The upper two-thirds of the trunk is dusky with two rows of irregular longitudinal pale streaks in young specimens with irregular reticulations in juveniles and ocellated dark spots in the larger adults. The ventral one-third of trunk is pale in juveniles, forming tiny specks in intermediate sizes and adults. The upper two-thirds of the caudal region of the body in juveniles is dusky, with a single longitudinal row of irregular pale spots. In the adults, there are many ocellated dusky spots. The ventral one-third of caudal is pale in juveniles changing to dusky in adults.

In large adults, the body and dorsal fin may be profusely spotted whereas in others, the spots are fewer and scattered. This may represent sexual dimorphism but more specimens are needed for clarification.

The color in one young specimen, 175 mm. in length, collected at the surface of the water, was very pale with dusky pigmentations beneath the outer skin.

Remarks

This species, as was shown above, passes through a definite change in dentition, body form, and color pattern from juveniles to adults. It takes its place with numerous other fishes which have been shown to make similar changes, such as in *Trachypterus rexsalmonorum,* the *Acronurus* stage in the acanthurids, and the *Ophioblennius* stage in salarian blennies.

ACKNOWLEDGMENTS

I especially thank Dr. Arthur D. Welander, School of Fisheries, University of Washington, and Dr. George S. Myers and Miss Margaret Storey, both of Natural History Museum, Stanford University, for loan of materials for this study.

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FOOD OF THE PACIFIC SARDINE, *SARDINOPS CAERULEA*, FROM CENTRAL BAJA CALIFORNIA AND SOUTHERN CALIFORNIA[1]

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INTRODUCTION

In 1949 a study of the food of the Pacific sardine was begun as a part of the California Cooperative Sardine Research Program. In this phase of the program the California Department of Fish and Game collects stomach samples for analysis by the Scripps Institution of Oceanography of the University of California, La Jolla. In the course of the preliminary work, 42 stomachs were examined by the Department and the results are here presented.

METHODS

The digestive tract was dissected into three parts: the gullet to the cardiac portion of the stomach, the cardiac and pyloric portions, and the intestine. Each part was examined under a dissecting microscope (7X to 20X) and a count made of the larger organisms. Each part was then diluted, an aliquot portion placed in a Sedgewick-Rafter cell and the smaller organisms counted under a compound microscope (150X).

No attempt was made to determine the volume of the macroplankton or microplankton in the digestive tracts. (Technically, the smallest organisms found are nannoplankton.) The food organisms were so mixed and compressed, especially in the pyloric portion of the stomach, that no feasible method of separating them for volumetric analysis was apparent. Counts of food organisms and occurrences were recorded and a note was made whether phytoplankton or zooplankton made up the bulk of the contents by inspection.

RESULTS

Four samples of sardines, 24 fish, from central Baja California and four samples, 18 fish, from Southern California were examined (Table 1). Copepods occurred in all 42 fish examined, phytoplankton in 28 and dinoflagellates[2] in 28 (Tables 2 and 3). Crustaceans and crustacean parts made up the bulk of all stomachs examined. Phytoplankton was more numerous than zooplankton, but did not make up a very large percentage of the total volume. The size of the food organisms ranged from .02 mm. to 13.7 mm.

[1] Submitted for publication May, 1952.
[2] Dinoflagellates are included by many authors under phytoplankton.

TABLE 1

Origin and Size of Sardines Sampled

Sample	Date	Time	General location	Number of fish	Standard length mm.
			Central Baja California		
1	September 28, 1949	2000	5 mi. NW. Blanca Bay	10	144–184
2	September 29, 1949	2100	S. Shore Sebastian Vizcaino Bay	3	112–136
3	September 30, 1949	0100	16 mi. SE. Point Eugenia	1	147
4	October 1, 1949	2100	Thurloe Bay	10	80–89
			Southern California		
5	November 21, 1949	1900	7 mi. SE. Point Dume	1	207
6	November 21, 1949	1930	6 mi. SE. Point Dume	7	196–218
7	November 22, 1949	1605	7.5 mi. W. Point Dume	5	197–226
8	November 22, 1949	2000	West of Redondo Beach	5	198–213

Hart and Wailes (1932) found that sardines sampled off British Columbia contained a greater volume of phytoplankton than anything else. This might be due to the heavier concentrations of phytoplankton to the north. Scofield (1934) showed that as the sardines grow larger, the gill rakers develop into finer straining organs, and he suggested that this might increase their ability to filter smaller organisms. Lewis (1929) found high diatom counts from fish sampled in the San Diego area, but Parr (1930) raised the question of whether these diatoms were ingested incidentally while the fish were feeding on the larger copepods. It seemed that some of the diatoms ingested by the eight samples of sardines discussed in this paper were not digested. Some of the heavier walled diatoms were intact and the green pigment still in them in the lower part of the intestine. The diatom and dinoflagellate count may have been high in proportion to the other organisms, since the larger, softer forms were no longer recognizable by the time they reached the lower digestive tract.

The numbers of the macroplanktonic organisms in the sardines from central Baja California made up 85 percent of the total while the microplanktonic organisms only 15 percent. The Southern California sardines yielded 80.5 percent microplanktonic organisms while the macroplankton comprised 19.5 percent by number. Although this shows an increase of smaller organisms in the digestive tracts of fish sampled from Southern California, the fish from central Baja California were also much smaller. It would be impractical to suggest a causal relationship for the difference in the diet of fish from these two regions based on so few samples.

There has been much speculation on the method of feeding of the sardine. One school of thought is that it is a filter feeder, the other one is that it is a particulate feeder, i.e., picks out each food particle. The size and quantity of the smaller organisms ingested are evidence that the sardine does filter feed at least at times. On one of the routine sardine survey cruises sardines were taken which were gorged with postlarval anchovies approximately an inch and a half long. It is extremely doubtful that these could have been taken by filter feeding. Sardines will strike and

can be caught on fishhooks, either with red beads or bits of yarn on the hooks, or sometimes on just shiny hooks. This is obviously visual stimulation and particulate feeding.

Another question which is raised and which might be of more importance is whether the sardine is selective or nonselective in its diet. A preference for certain types of food could possibly influence the distribution of the fish. From examinations of digestive tracts of the sardine, it becomes apparent that the sardine is omnivorous and ingests an extremely large number of species with a great range in size. Only one plankton sample was examined from the same area where a sardine school was sampled. Analysis showed that while the plankton sample contained approximately 9.5 times as many copepods as cyphonautes larvae, the stomachs yielded eight times as many cyphonautes as copepods. Lack of knowledge of how long these cyphonautes larvae were ingested before sampling makes it unwise to attach much significance to this one sample.

Kishinouye (1907) demonstrated that the Japanese sardine, *Sardinops melanostica,* also had a diverse appetite. The stomach contents of fish taken in bays and inlets suggested a more uniform diet than those taken in the open sea. Kishinouye also reports inorganic substances such as grains of sand and sponge spicules in the stomachs which he believes is due to the inability of the sardines to select between similar sizes of organisms while filter feeding. He expresses his belief, however, that sardines can select to a certain degree by manipulation of the gill rakers.

CONCLUSIONS

1. The bulk of the stomach contents of the 42 fish sampled was crustaceans and crustacean parts.
2. The type of food organisms occurring in most stomachs was copepods.
3. There was numerically more macroplankton in the stomachs of fish from central Baja California and more microplankton from Southern California. The fish sampled from central Baja California were smaller fish than from Southern California.
4. Sardines are both particulate and filter feeders.
5. Many more stomachs and plankton samples need to be examined in order to determine if the sardine is selective in its feeding habits.

TABLE 2

Occurrences of Food Organisms in Stomachs of Sardines Sampled From Central Baja California

Food organisms	Numbers									
	Sample 1 10 fish		Sample 2 3 fish		Sample 3 1 fish		Sample 4 10 fish		Totals 24 fish	
	Organisms	Fish	Organisms	Fish	Organisms	Fish	Organisms	Fish	Organisms	Fish
Diatomales										
Stephanopyxis sp.	569	3							569	3
Coscinodiscus sp.	152	3							152	3
Chaetoceros sp.	1	1							1	1
Ditylum sp.	4	1							4	1
Biddulphia sp.	24	1							24	1
Thalassiothrix sp.					111	1			111	1
Navicula sp.	309	9							309	9
Nitzschia sp.	381	4							381	4
Surirella fastuosa	1	1							1	1
Total Diatomales	1,441	10			111	1			1,552	11
Unidentified Algae	1,207	10							1,207	10
Total Phytoplankton	2,648	10			111	1			2,759	11
Silicoflagellata					9	1			9	1
Dinoflagellata										
Noctiluca sp.	8	1							8	1
Peridinium sp.	342	3			5	1			347	4
Ceratium sp.	4	1							4	1
Other Dinoflagellata	22	5					8	1	30	6
Total Dinoflagellata	376	8			5	1	8	1	389	10

Radiolaria[1]	1,761	9							1,761	9
Foraminifera	2	1							2	1
Chaetognatha	282	3	1	1	8	1			291	5
Bryozoa										
Cyphonautes larvae	166	9			46	1	14,218	10	14,430	20
Pelecypoda										
Unidentified			8	1					8	1
Veliger larvae	23	1							23	1
Total Pelecypoda	23	1	8	1					31	2
Polychaeta										
Trochophore larvae	2	1							2	1
Cladocera			142	3					142	3
Ostracoda	1	1	2	2					3	3
Copepoda										
Calanus finmarchicus	423	7							423	7
Other Copepoda	686	10	736	3			1,801	10	3,223	23
Copepod nauplii	149	3	19	2	10	1			178	6
Total Copepoda	1,258	10	755	3	10	1	1,801	10	3,824	24
Schizopoda										
Mysidacea			13	1					13	1
Euphausiacea			3	1					3	1
Unidentified	178	9	1	1					179	10
Total Schizopoda	178	9	17	2					195	11
Stomatopoda										
Squilla sp.	1	1	4	1					5	2

[1] The heading Radiolaria may contain some heliozoans.

TABLE 2—Continued

Occurrences of Food Organisms in Stomachs of Sardines Sampled From Central Baja California

Food organisms	Numbers									
	Sample 1 10 fish		Sample 2 3 fish		Sample 3 1 fish		Sample 4 10 fish		Totals 24 fish	
	Organisms	Fish	Organisms	Fish	Organisms	Fish	Organisms	Fish	Organisms	Fish
Decopoda										
Brachyurans	1	1		1					6	2
Brachyuran zoea	5	4	98	3					103	7
Brachyuran megalopa	9	1	2	1					11	2
Total Decopoda	15	5	105	3					120	8
Other Crustacea	237	8	440	3			648	5	1,325	16
Invertebrate eggs	5,599	10	23	3			64	3	5,686	16
Appendiculariidae										
Oikopluera sp.	49	4	14	2			648	5	711	11
Pisces										
Pneumatophorus diego (larvae)	1	1							1	1
Fish eggs			658	3	5	1			663	4

TABLE 3

Occurrences of Food Organisms in Stomachs of Sardines Sampled From Southern California

Food organisms	Numbers									
	Sample 5 1 fish		Sample 6 7 fish		Sample 7 5 fish		Sample 8 5 fish		Totals 18 fish	
	Organisms	Fish	Organisms	Fish	Organisms	Fish	Organisms	Fish	Organisms	Fish
Diatomales										
Stephanopyxis sp.			11,513	2					11,513	2
Coscinodiscus sp.	116	1	640	5	1,570	3	20	2	2,346	11
Rhizosolenia sp.			30	1			34	1	64	2
Bacteriastrum sp.	116	1	686	4	1,269	4	12,549	5	14,620	14
Ditylum sp.							16	1	16	1
Grammatophora sp.			660	1					660	1
Navicula sp.			190	1	3,193	4	11,412	5	14,795	10
Nitzschia sp.							6	1	6	1
Total Diatomales	232	1	13,719	6	6,032	5	24,037	5	44,020	17
Unidentified Algae	464	1	677	4	2,446	4			3,587	9
Total Phytoplankton	696	1	14,396	6	8,478	5	24,037	5	47,607	17
Silicoflagellata			1,245	4	7,272	3	1,248	5	9,765	12
Dinoflagellata										
Prorocentrum micans	4,752	1	22,687	7	259,543	5	6,545	5	293,527	18
Noctiluca sp.			463	3					463	3
Dinophysis sp.	1,632	1	4,358	7	16,033	3			22,023	11
Gonyaulax sp.	695	1	1,390	3					2,085	4
Peridinium depressum			879	2					879	2
Peridinium micrapium			320	3					320	3
Peridinium sp.	2,202	1	10,395	7	52,082	5	8,228	5	72,907	18
Oxytoxum sp.			93	3					93	3

TABLE 3—Continued

Occurrences of Food Organisms in Stomachs of Sardines Sampled From Southern California

Food organisms	Numbers									
	Sample 5 1 fish		Sample 6 7 fish		Sample 7 5 fish		Sample 8 5 fish		Totals 18 fish	
	Organisms	Fish	Organisms	Fish	Organisms	Fish	Organisms	Fish	Organisms	Fish
Dinoflagellata—Continued										
Ceratium fusus			145	2					145	2
Ceratium furca			110	2					110	2
Ceratium tripos	2,897	1							2,897	1
Ceratium divaricatum			531	3					531	3
Ceratium sp.			3,679	5	2,212	3	359	3	6,250	11
Podolampas sp.	116	1	430	4					546	5
Other Dinoflagellata					153	1	4	1	157	2
Total Dinoflagellata	12,294	1	45,480	7	330,023	5	15,136	5	402,933	18
Radiolaria[1]			2,830	6	94	3	32	1	2,956	10
Tintinnoinea										
Tintinnopsis sp.			82	2					82	2
Heliocostomella sp.	116	1	330	1					446	2
Favella sp.			99	1					99	1
Parafavella sp.	232	1	512	4					744	5
Parundella sp.	348	1	850	5					1,198	6
Tintinnus sp.	116	1	4	1					120	2
Other Tintinnoinea			163	3					163	3
Total Tintinnoinea	812	1	2,040	5					2,852	6
Chaetognatha					4	1			4	1

Bryozoa										
Cyphonautes larvae							2	2	2	2
Pelagothurida[2]							4	1	4	1
Gastropoda			1	1					1	1
Cladocera										
Evadne sp.			2	1	38	3			40	4
Other Cladocera			20	2	2	1			22	3
Total Cladocera			22	3	40	3			62	6
Copepoda										
Calanus finmarchicus					322	2			322	2
Eucalanus elongatus			2	1					2	1
Microstella rosea			15	1					15	1
Microcalanoids	1,500	1	2,504	7	1,540	3	231	4	5,775	15
Oithona sp.			1	1	4	2	14	2	19	5
Corycaeus sp.	35	1	748	7	49	2	1	1	833	11
Other Copepoda	232	1	170	3	16,188	5	92	4	16,682	13
Nauplii			900	7					900	7
Total Copepoda	1,767	1	4,340	7	18,103	5	338	5	24,548	18
Schizopoda			2	2	216	5	1	1	219	8
Decopoda										
Brachyuran zoea	5	1			1	1			6	2
Other Crustacea			92	3	105	3	4	3	201	9
Invertebrate eggs	1,507	1	16,978	7	63,160	5	5,631	5	87,276	18
Appendiculariidae										
Oikopleura sp.			92	3	105	3	4	3	201	9
Fish eggs			98	2	338	2	49	4	485	8

[1] The heading Radiolaria may contain some heliozoans.

[2] The specimens of pelagothurida found were so clearly defined that their identity was not questioned; however, it was discovered later that such an occurrence in these waters would be considered unusual. Unfortunately the specimens were not saved.

TABLE 4

Numbers of Organisms per Sample Found in Sardine Stomachs

Type of food organism	Central Baja California					Southern California				
	Sample 1	Sample 2	Sample 3	Sample 4	Total	Sample 5	Sample 6	Sample 7	Sample 8	Total
Microplankton										
Phytoplankton	2,648		111		2,759	696	14,396	8,478	24,037	47,607
Protozoans	2,139		14	8	2,161	13,106	51,595	337,389	16,416	418,506
Totals	4,787		125	8	4,920	13,802	65,991	345,867	40,453	466,113
Percentages	38.0		64.5		15.0	81.0	75.5	81.0	87.0	80.5
Macroplankton										
Crustacea	1,690	1,465	10	2,449	5,614	1,772	4,434	18,447	383	25,036
Others	523	23	54	14,866	15,466		93	109	10	212
Eggs	5,599	681	5	64	6,349	1,507	17,076	63,498	5,680	87,761
Totals	7,812	2,169	69	17,379	27,429	3,279	21,603	82,054	6,073	113,009
Percentages	62.0	100.0	35.5	100.0	85.0	19.0	24.5	19.0	13.0	19.5
All food organisms	12,599	2,169	194	17,387	32,349	17,081	87,594	427,921	46,526	579,122

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DEVELOPMENT THROUGH THE PROLARVAL STAGE OF ARTIFICIALLY FERTILIZED EGGS OF THE PACIFIC SARDINE *(SARDINOPS CAERULEA)*[1]

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INTRODUCTION

Considerable data have been published on the early life history of the Pacific sardine (*Sardinops caerulea*). Many stages of the egg and larval development have been described from material collected in plankton tows by Scofield and Lindner (1930), Scofield (1934), and Ahlstrom (1943), but until now there has been no record of the development of living Pacific sardine eggs fertilized and controlled in the laboratory. Cunningham (1891), who recorded the development of artificially fertilized eggs of the European sardine (*Sardina pilchardus*), stated that running ripe female sardines were rarely taken by the commercial sardine fishermen. Likewise, there have been very few running ripe female Pacific sardines collected; in fact, Clark (1934) found but four running ripe female sardines in 11 years of sampling the commercial catch.

Recently, during routine sardine cruises of the department's research vessel M. V. YELLOWFIN, an effort was made to find mature fish, and on April 12, 1952, George Pratt, deckhand aboard the YELLOWFIN, brailed a ripe female from the surface where she was attracted by a 750-watt light. The eggs were stripped and fertilized using two ripe males taken from a sample of 164 fish collected several minutes before the capture of the female. In the succeeding days the embryological, prolarval and early postlarval stages were observed and recorded. This paper presents the details of the development of these eggs and larvae.

I wish to express my gratitude to the members of the staff of the Bureau of Marine Fisheries at Terminal Island for their helpful suggestions in the rearing of the larvae and in the preparation of the manuscript, and to the crew of the YELLOWFIN whose interest and cooperation was of considerable aid throughout the experiment.

METHODS

The mature sardines were collected 20 miles off San Cristobal Bay, Baja California, Mexico, at 10 p.m. in 800 fathoms of water (Lat. 27° 15.0′ N., Long. 114° 59.6′ W.). The fish were taken from a small mixed school of sardines and Pacific mackerel that was spread thinly near the surface of the water. Surface water temperature was 16.0° C. (60.8° F.) at the time of collection.

[1] Submitted for publication June, 1952.

About 3,000 eggs were stripped into a pint jar half filled with water, sperm was added, and the fertilized eggs divided evenly into eight quart jars and one three-gallon jar each three-fourths full of sea water. Temperatures were taken hourly and frequent changes of fresh sea water were made during the period of incubation of the eggs. The larval stages were treated similarly until the vessel reached port at which time an aerating apparatus was installed in the three-gallon jar. Feeding of the larvae was attempted with yolk of boiled egg and newly-hatched brine shrimp nauplii.

A complete series of living egg and larval stages was observed under a wide-focus dissecting microscope with 10X oculars and 3X objectives. A series of stages was also preserved in 5 percent formalin for future study. The temperature of the water was kept between 16.1° C. (61.0° F.) and 17.6° C. (63.7° F.) with a mean average temperature of 16.8° C. (62.2° F.). At 20 hours after fertilization, when the embryos were in their six somite stage, several dozen eggs were placed in two quart jars where they were kept at 22.2° C. (72.0° F.).

DESCRIPTION OF THE MATURE FISH AND OVARY

The female, 172 mm., standard length (eight inches total length), proved to be a three-ring fish or in her fourth year. Radovich (1952) found that three-ring fish (1948 year class) from the Sebastian Vizcaino Bay region of Baja California range from 161 mm. to 220 mm. in standard length. Fish of the 1948 year class from Southern California ranged from 181 mm. to 250 mm. in standard length, so this fish collected off San Cristobal is representative of the sardines from the central Baja California region.

The female came to the light about 10 minutes after the school of fish had been sighted and sampled with an explosive, and it is possible that she was in the act of spawning when captured. Her actions in the water were unlike those of a fish affected by an explosive charge, and dissection proved that the air bladder was intact and inflated. Also, there was no evidence of ruptured capillaries along the edges of the air bladder or in the viscera as is present in sardines that have been slightly stunned by an explosive charge.

The condition and structure of the ovary compared favorably with that of a mature ovary as given by Clark (1934). The ripe transparent eggs completely filled the lumen of the oviduct and flowed freely from the fish. The eggs were noticed when the female was brailed and placed in a net container on the deck before the fish had been handled. The ovary contained eggs of three distinct groups: the mature, transparent eggs with a mean diameter of 1.15 mm., others with a mode at 0.40 mm. in diameter, and a third group, classed as immature, with a mode at 0.12 mm.

DEVELOPMENT OF THE EGGS

Drawings of all stages including the 128-blastomere stage to hatching have been published by Ahlstrom (1943) so, to prevent duplication of material, only the stages unavailable to Ahlstrom are presented here (Figures 1-4). However, Table 1 gives a record of developmental rates

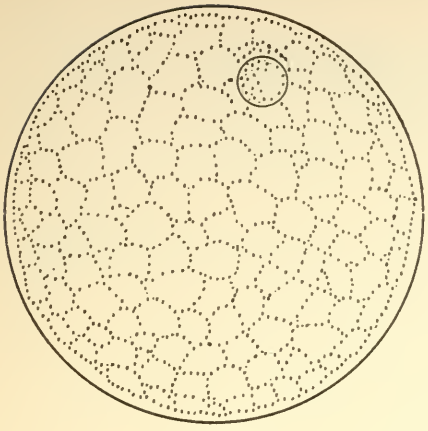

FIGURE 1
Just-fertilized egg (0 hours)

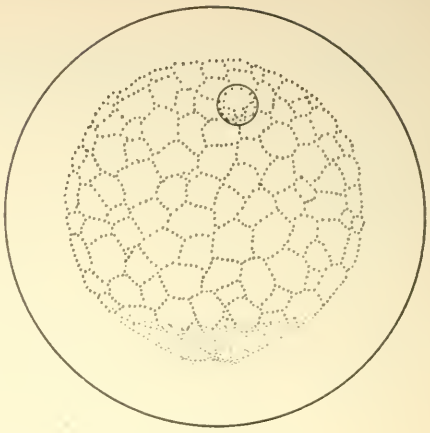

FIGURE 2
Two blastomere stage (1½ hours)

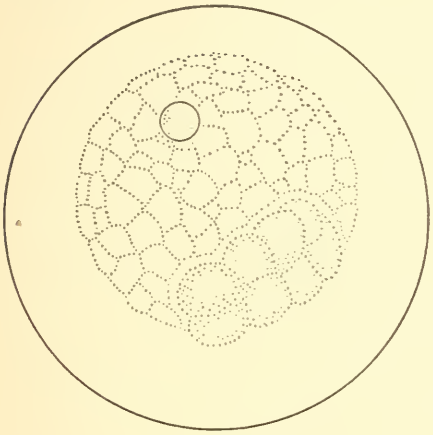

FIGURE 3
Eight blastomere stage (2 hours)

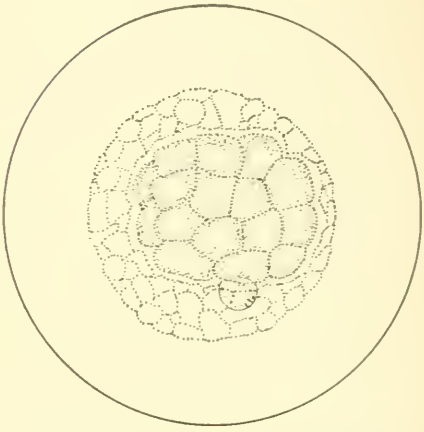

FIGURE 4. Sixteen blastomere stage (2¼ hours)

from a series obtained from living material and indicates the time interval between the successive stages.

When the eggs were placed in sea water for fertilization they floated and formed a layer near the top of the jar. When transferred into the other jars they tended to adhere to each other due to an adhesive substance about them. In about two hours this adhesive substance was lost and the eggs were found to be scattered uniformly throughout the jars. This substance could have been slime from the adult fish as they were stripped down, for Clark (personal communication) found no such material about the eggs in the mature ovaries.

The perivitelline space was small or nonexistent in the unfertilized egg. Clark (1934) stated that ripe unfertilized sardine eggs placed in sea water developed a small perivitelline space ranging from 0-0.16 mm. in width. In the fertilized sardine egg the formation of this space is caused by the expansion of the capsule (vitelline membrane) through absorption of water until the egg reaches its maximum diameter in about 10 hours. This "water hardening" process is demonstrated in Table 2 which shows the time and stage of development of the eggs as the capsule swells. The diameter of the yolk remains unchanged throughout this period.

TABLE 1

Embryological Development of the Sardine (Sardinops caerulea)
Eggs Held at Average Temperature of 16.8° C. (62.2° F.)

Hours after fertilization	Stage of development	Remarks
1	Blastodermal cap formed	Perivitelline space forming. Eggs near top of water. Yolk sac tends to remain in upper portion of the capsule, with the oil globule uppermost.
1½	2-4 blastomeres	
2	8 blastomeres	One 16 blastomere stage found at this time.
2¼	16 blastomeres	Blastomeres protruding well from the yolk material—easily seen.
2½	32 blastomeres	Eggs now suspended uniformly in jars, not all near the surface as previously.
3	64 blastomeres	The rate of cleavage is fairly uniform. There is very little overlapping of stages.
3½	128 blastomeres	
10	Blastodisc well formed. (Early germ ring)	"Water hardening" completed. (1.83 mm. average diameter).
13	Embryonic shield	Germ ring nearing equator.
19	Early embryo stage.	Blastopore closing. Yolk sac in upper portion of capsule.
20	6 somite stage	Only the somites clearly seen in the living material are counted. A few eggs are starting to die and turn white when they sink to the bottom of the jars.
24	12 somite stage	
30	28 somite stage	
35	35 somite stage	Tail coming free from yolk sac.
38	42 somite stage	Cerebral hemispheres now defined.
43	48 somite stage	Heart beats observed (120 per minute).
47	Starting to hatch	Probably eggs with damaged capsules.
55	Peak of hatching	Over three-fourths of the eggs hatched between 54 and 56 hours after fertilization. The prolarvae are suspended in water with the yolk sac upward. Capsules sink to the bottom of the jars upon hatching of the larvae.
60	Hatching completed	

The yolk containing a single oil globule (0.16 mm. in diameter) and the segmented yolk material has a specific gravity less than that of sea water so tends to remain in the upper portion of the capsule (Figure 3). In a 20-hour specimen the young embryo was situated about in the center of the egg with the yolk sac uppermost and nearly touching the capsule. Ten hours later, after some of the yolk material was used up, the embryo lay in the lower portion of the capsule.

The mortality of eggs during the period of incubation was surprisingly small. None were found dead until 20 hours had elapsed and during the entire period up to hatching not over 70 had died. The eggs held at 16.8° C. started hatching at 47 hours after fertilization. Only two hatched at this time and it is quite possible that this resulted from a mechanical rupture of their capsules occurring during a change of water. Over three-fourths of the eggs hatched between 54 and 56 hours after fertilization. By 60 hours all had hatched. Ahlstrom (1943), using a series of sardine

TABLE 2

The Swelling of the Capsule of the Fertilized Sardine Egg. After 10 Hours All Diameters of Eggs Fell Within the Range of the 10-hour Group

Eggs Held at 16.8° C. (62.2° F.) and Preserved in 5 Percent Formalin

Hours after fertilization	Stage of development	Average diameter in mm.	Range of diameter in mm.	Number of eggs measured
0	Just fertilized	1.15	1.10-1.20	10
1	Blastodermal cap	1.38	1.31-1.41	10
2	8-16 Blastomeres	1.64	1.62-1.67	3
3	64 Blastomeres	1.68	1.64-1.73	8
5½	Early Blastodisc	1.73	1.69-1.76	10
10	Early Germ Ring	1.83	1.71-1.90	10

eggs collected in plankton hauls, compiled a table of developmental rates. This table indicates that at 16.8° C. the time required for sardine eggs to reach the stage immediately preceding hatching is approximately 53 hours. This is surprisingly close to the time in which three-fourths of our eggs hatched. The eggs held for part of their development at 22.2° C. all hatched between 43 and 46 hours after fertilization. There were eight eggs lost out of the 50 held at this temperature.

On May 22, 1952, another female sardine (223 mm. S. L.) was taken in 16.3° C. (61.3° F.) water off Huntington Beach, California, in a sample of 15 fish blasted under the light at 1 a.m. This female showed evidence of having spawned shortly before capture. Six transparent eggs were present in the lumen of the oviduct close to the vent. These were teased out and placed in two jars of sea water, each containing three eggs. A male sardine (213 mm. S. L.) was found with large white gonads but was not in running condition. A small amount of testicular material was dissected out and placed in a jar with three of the eggs. Two of these eggs were injured in handling but the third was viable and fertilization took place. The other nonfertilized eggs were allowed to stand for three hours in the other jar of sea water. No perivitelline space was formed in this time in the unfertilized eggs. After three hours had elapsed a small amount of water from the jar containing the sperm was added to the unfertilized eggs. Fertilization took place in one egg and the perivitelline space formed as usual.

Measurements were made of 100 eggs from this ovary and two distinct groups with modes at 0.40 mm. and 0.13 mm. were found. The eggs of the larger group were gray-white in color, unlike the yellow-orange eggs of the same diameter found in a ripening ovary.

LARVAL DEVELOPMENT

Immediately upon hatching and during the prolarval period when the yolk sac is still fairly large, the fish remain belly up, floating and swimming about near the surface. After the light yolk material and oil globule are used up the fish, if they remain motionless, sink slowly to the bottom

of the jar. Occasionally they swim upwards, then lie still and sink downward again. This sinking downwards and swimming upwards is repeated over and over again.

The growth rate of the prolarval and early postlarval sardine is given in Figure 5. The yolk sac was used up in three days at 16.8° C. and in $2\frac{1}{2}$ days at 22.2° C. Many larvae died soon after the yolk material was

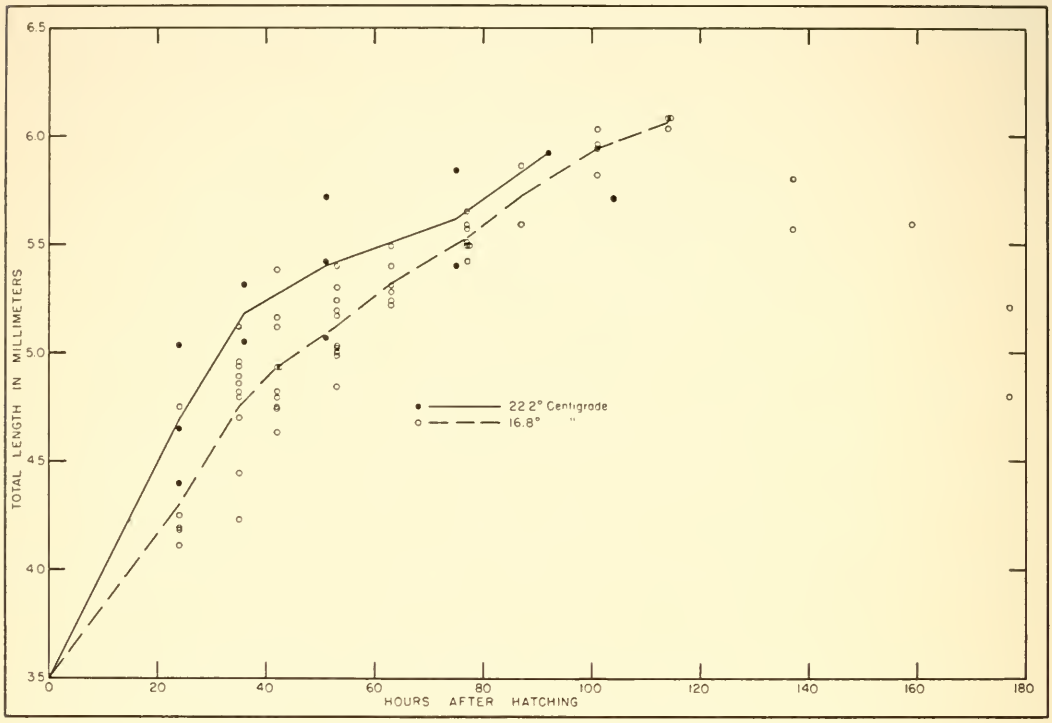

FIGURE 5. Growth of the sardine larvae at 16.8° C. and 22.2° C. Lines drawn through means of groups at each sample.

absorbed, but those remaining showed a steady increase in total length up to the fifth day after which time there was a progressive decrease for larvae held at both temperatures (Figure 5). This phenomenon of larval fish decreasing in total length after the absorption of the yolk material has been noted by several authors such as Orcutt (1950), who observed this same decrease in total length of larval starry flounder (*Platichthys stellatus*).

In the newly hatched larvae there are two dorsal rows of pigment spots parallel to each other, one on either side of the notochord. This pigment migrates downward along the sides soon after hatching and accumulates anteriorly over the gut and optic lobes and posteriorly in a position under the gut and in the lower caudal fin fold. This migration of the melanophores is illustrated in Figures 6-9. In Figure 6, a 24-hour larva, the dendritic melanophores can be seen migrating downward in the caudal region and anteriorly about a third of the distance between the anal pore and the posterior edge of the yolk sac. Under bright illumination this pigment is brownish-yellow in color. The extremities of the dendrites are very delicate, forming a reticulate network over the dorsal surface of the somites and out onto the nape, interorbital space and nasal pit areas of the head region. As migration proceeds these dendritic arms of pigment become compact and tend to form dark blotches over the lateral surfaces of the

body. This migration of pigment was completed in all individuals by 60 hours after hatching. The rate of migration varied considerably between individuals held at the same temperature.

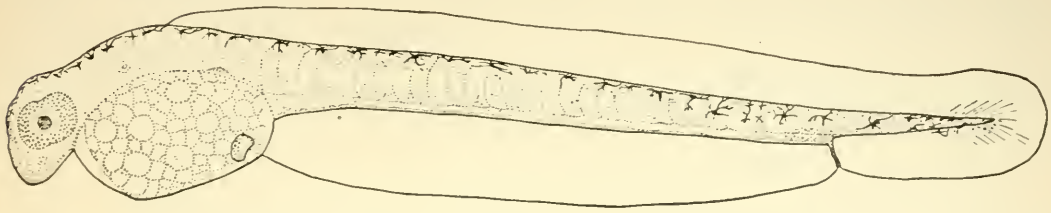

FIGURE 6. Twenty-four hour larva. Total length 4.11 mm.

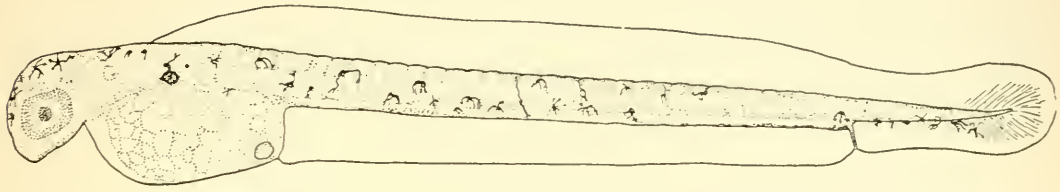

FIGURE 7. Thirty-six hour larva. Total length 4.86 mm.

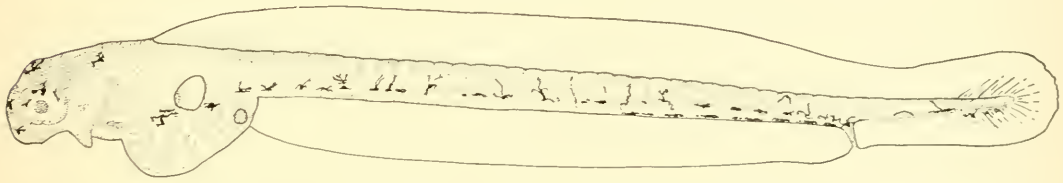

FIGURE 8. Forty-eight hour larva. Total length 5.30 mm.

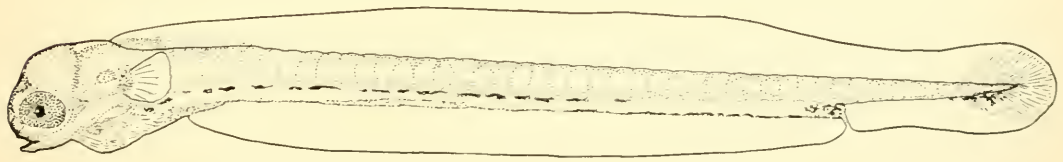

FIGURE 9. Three-day larva. Total length 6.03 mm.

The structural development of the larvae is illustrated in Figures 6-9. A brief description of this development follows: In the 24-hour larva (Figure 6) there is a slight constriction of the upper lobe of the caudal fin fold. The lepidotrichia of the caudal fin fold can be seen as can the small pectoral fins near the dorsal edge of the yolk sac. The oil globule is still fairly large but is more oval than spherical in shape. The head region is characteristically bent over the yolk sac at this stage, but very soon afterwards straightens out (Figure 7). In the 36-hour larva (Figure 7) there is further constriction of the caudal fin fold posterior of the anal pore and the lepidotrichia of the caudal fin fold are more numerous and longer. The pectoral fins are noticeably larger and can be seen in outline under proper illumination. The cerebral hemispheres are very marked. The yolk sac is not much smaller in proportion to the body length than in the 24-hour larva. In the 48-hour larva (Figure 8) there is a marked decrease in the size of the yolk sac, but the oil globule still remains comparatively large. The pectoral fins are much larger and can

be seen by the naked eye. The pigment migration has been completed in some specimens except on the optic lobes, but some individuals are still found to be lagging considerably at this time. In most samples the pigment from the head region is becoming compact and is beginning to move toward the optic lobes. In the 3-day larva (Figure 9) the optic lobes are well pigmented and appear shiny black in both the living and preserved material. There is still a remnant of yolk material in a few individuals. The pectoral fins have now become much larger and pointed, but there is no evidence as yet of formation of rays in any of the fins.

Considering the abnormal conditions under which the postlarvae were held they are not described here. Yolk of boiled egg and brine shrimp nauplii were fed to some of the larvae with no apparent effect. Some larvae kept aside without feeding fared as well as those given food.

Successful techniques for feeding of such tender, small larvae are unknown. However, efforts are being made to develop such techniques (Morris, 1951).

SUMMARY

1. Eggs of the sardine were fertilized and their development was followed. The period of incubation was approximately 56 hours at 16.8° C. (62.2° F.). At 20 hours after fertilization about 50 eggs were placed in 22.2° C. (72.0° F.) water with no apparent harmful effects. These eggs then developed at a much faster rate and hatched from 43 to 46 hours after fertilization.

2. The fertilized eggs of the sardine undergo a stage of "water hardening" in which the capsule (vitelline membrane) expands to form a large perivitelline space. In a period of about ten hours the eggs held at 16.8° C. increased from an average diameter of 1.15 mm. to 1.83 mm.

3. Eggs remaining in the lumen of the oviduct after a spawning were found to be viable. Unfertilized eggs from a spawned-out female were left standing for three hours in sea water. Sperm which was also left standing for three hours was added to these eggs and fertilization took place.

4. The larvae consumed the yolk sac in three days at 16.8° C. and in 2½ days at 22.2° C. Many of them remained alive and increased in total length until the fifth day after which time they showed a steady decrease in total length. All larvae had died by the seventh day after hatching.

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PHEASANT COOPERATIVE HUNTING AREA RESULTS, 1951 [1]

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INTRODUCTION

The cooperative hunting area program successfully initiated by the Department of Fish and Game in 1949 and expanded in 1950 was continued in 1951. During the 1951 hunting season, 11 areas were operated for pheasant hunting, consisting of the 10 areas which functioned in 1950 plus the Twitchell Island area in the Delta region. Figure 1 shows the location of the areas. The Sartain area continued to be the single charge area collecting the daily fee of $2 per hunter allowed by the cooperative hunting area law. No charge was made for hunting on the 10 other areas.

Rules and regulations and mechanics for management of the hunting areas were practically the same as in previous years (Harper, et al., 1950; Hart, et al., 1951).

The pheasant hunting season started Saturday, November 17, and continued for 10 days, with a daily bag limit of two cocks and a season limit of 10.

TABLE 1

Size of Each Zone in Cooperative Hunting Areas and Seasonal Capacity for Hunters [1]

Area	OPEN ZONE		RESTRICTED ZONE		CLOSED ZONE	TOTAL
	Acres	Seasonal hunter capacity [2]	Acres	Seasonal hunter capacity	Acres	Acres
Staten Island	6,745	5,000	1,320	At	1,135	9,200
Ryer Island	11,288	6,650	1,737	discretion	325	13,350
Sutter Basin	12,671	8,000	2,075	of	2,800	17,546
Natomas	16,684	12,000	2,937	landowner	2,000	21,621
Grimes	19,213	18,000	4,567		2,160	25,940
Sartain	12,530	11,500	2,550		50	15,130
Butte Creek	8,612	11,500	1,705		500	10,817
Meridian	8,556	6,300	1,050		50	9,656
Los Banos	6,116	3,200	212		4,382	10,710
Firebaugh	7,700	4,500	1,300		4,000	13,000
Twitchell Island	5,720	3,500	458		641	6,819
Totals	115,835	90,150	19,911		18,043	153,789

[1] There were some slight changes in zone acreages during the hunting season.
[2] Minimum number of hunters that could be accommodated for the season (hunter days). No allowance is made for hunters that hunt only part of a day and are then replaced by other hunters.

[1] Submitted for publication May, 1952. Federal Aid in Wildlife Restoration Act, California Project 22-R. The authors wish to express their appreciation to numerous employees of the Department of Fish and Game who aided in gathering or compiling the information presented herein, especially to George Metcalfe, Ernest Clark, Alvin Stewart and Ward Hill.

The total acreage in cooperative hunting areas increased from 138,634 in 1950 to 153,789 in 1951. Table 1 presents information on zone acreages and hunter capacity for each area.

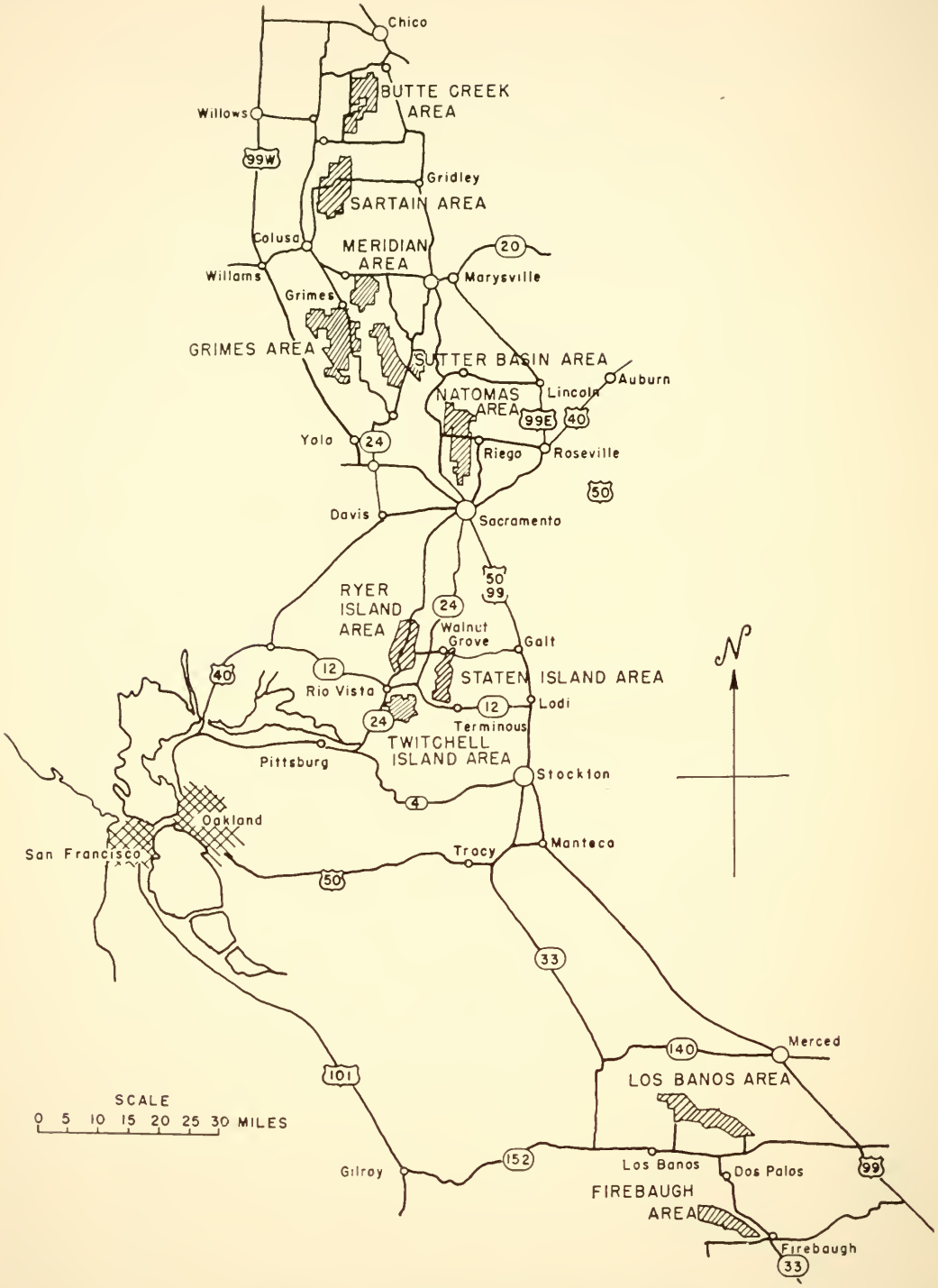

FIGURE 1. Cooperative Hunting Areas, 1951

TABLE 2

Number of Hunters, Pheasants Killed, and Success on Each Cooperative Hunting Area

Area	PERMITS ISSUED BY STATE				PERMITS ISSUED BY LANDOWNERS[1]		TOTALS		
	Number		Kill by State permittees		Number returned	Reported kill	Number of hunter days[2]	Kill[2]	Success (birds per hunter day)
	Issued	Returned	Checked	Calculated					
Staten Island	3,184	3,140	1,147	1,163	99	123	3,283	1,286	0.39
Ryer Island	3,827	3,744	1,428	1,460	398	389	4,225	1,849	.44
Sutter Basin	6,193	5,922	2,592	2,711	291	336	6,484	3,047	.47
Natomas	10,297	9,940	2,547	2,638	513	368	10,810	3,006	.28
Grimes	8,706	8,372	4,039	4,200	51	61	8,757	4,261	.49
Sartain	1,616	1,511	949	1,015	233	172	1,849	1,187	.64
Butte Creek	5,229	5,127	1,441	1,470	231	240	5,460	1,710	.31
Meridian	3,089	2,946	1,751	1,836	85	81	3,174	1,917	.60
Los Banos	2,744	2,693	941	959	34	21	2,778	980	.35
Firebaugh	4,064	3,958	1,453	1,492	141	161	4,205	1,653	.39
Twitchell Island	3,592	3,523	793	809	84	76	3,676	885	.24
Totals	52,541	50,876	19,081	19,753	2,160	2,028	54,701	21,781	.40

[1] Restricted zone permits and reserved permits for open zones; number issued is unknown.
[2] Minimum figures because of incomplete information on hunting of landowners and their guests.

HUNTING SEASON RESULTS

Hunting Pressure and Kill

Table 2 presents the number of hunters, number of birds bagged, and hunter success for each area. Department operated checking stations issued 52,541 hunting permits, which was an increase of 4,652 from the previous year. A total of 50,876 hunters checked out through the checking stations with 19,081 pheasants, an increase in kill of 1,558 from 1950. The total bag calculated to have been taken by the 52,541 open zone permittees was 19,753, assuming that hunters who did not check out had the same success as those who did.

A much greater return of restricted area and reserved open zone permits issued by landowners was obtained than in the past. In previous years the reported kill by landowner permittees was insignificant and was lumped with the total checked kill. In 1951 these returns were so great, 2,160 permits with a reported kill of 2,028, that they made up a sizable percentage of the bag on some areas and, therefore, were tabulated separately in Table 2.

Combining the data from department and landowner issued permits gave a total bag of 21,781 pheasants. The actual total hunter use and bag of birds on the areas would be somewhat greater because information on hunting and birds bagged by landowners and their guests was incomplete.

Hunter success over-all was 0.40 birds per hunter day, nearly the same as the success of 0.39 birds per hunter day in 1950. The unstocked Sartain area continued to have the highest success, 0.64 birds per hunter day, mainly because of the fewer hunters using the charge area.

Composition of Kill

Table 3 shows a breakdown by areas of the checked kill for wild and game farm birds and further subdivides the game farm birds into categories according to when and where they were released. Stocked birds made up 49.7 percent of the total bag.

Planting and Kill of Game Farm Birds

Male pheasants were stocked for hunting on all areas except Sartain, where, according to Fish and Game Commission policy, state-reared pheasants may not be planted because of the charge for hunting. Table 4 summarizes the stocking and band return data by period and area of release.

The 15,267 cock pheasants planted gave an over-all return of 60.8 percent, varying from a low of 27.0 percent from the earliest plants, in July, to a high of 70.4 percent from birds stocked in season.

Number of Hunters Using Cooperative Hunting Areas

Hunting permit applications for the Grimes, Natomas, and Staten Island areas were placed in alphabetical order by hunters' names to determine the number of individual shooters using each of those areas. This was approximately a 42 percent sample of all permits issued. The

TABLE 3

Composition of Checked Kill on Each Area

Area	FROM STATE GAME FARM RELEASES				FROM LICENSED GAME BIRD CLUB RELEASES		COMBINED GAME FARM KILL		WILD KILL		Total checked kill
	Cooperative hunting area releases		Other releases		1951	Prior to 1951	Number	Percent of total kill	Number	Percent of total kill	
	1951	Prior to 1951	1951	Prior to 1951							
Staten Island	668	17		1			686	59.8	461	40.2	1,147
Ryer Island	654	20	2				676	47.3	752	52.7	1,428
Sutter Basin	948	17	4		63	7	1,039	40.1	1,559	59.9	2,592
Natomas	924	21	11	6	47	15	1,024	40.2	1,523	59.8	2,547
Grimes	1,179	24	8		19	11	1,241	30.7	2,798	69.3	4,039
Sartain			2	1	17	2	22	2.3	927	97.7	949
Butte Creek	975	10	20	5	5		1,015	70.4	426	29.6	1,441
Meridian	1,163	3			2		1,168	66.7	583	33.3	1,751
Los Banos	728	3	37	1			769	81.7	172	18.3	941
Firebaugh	1,253	7	59	12			1,331	91.6	122	8.4	1,453
Twitchell Island	501		1		1		503	63.4	290	36.6	793
Totals	8,993	122	144	26	154	35	9,474	49.7	9,607	50.3	19,081

TABLE 4

Summary of Releases and Kill of Game Farm Birds Liberated on All Areas, 1951

Date or area released	Number of cocks released	NUMBER OF RETURNS			TOTAL RETURNS	
		Cooperative hunting areas[1]	Licensed game bird clubs[2]	Others[3]	Number	Percent
By Date of Release						
July	204	52		3	55	27.0
September	340	95	1	4	100	29.4
October	852	391	4	7	402	47.2
Nov.-Preseason	10,189	5,889	22	221	6,132	60.2
Nov.-Inseason	3,682	2,566	2	23	2,591	70.4
Totals	15,267	8,993	29	258	9,280	60.8
By Area of Release						
Staten Island	1,083	668		8	676	62.4
Ryer Island	1,000	654		11	665	66.5
Sutter Basin	1,675	948	13	19	980	58.5
Natomas	1,620	924	11	27	962	59.3
Grimes	1,816	1,179		26	1,205	66.4
Sartain						
Butte Creek	1,838	975		27	1,002	54.5
Meridian	2,127	1,163	5	62	1,230	57.8
Los Banos	1,025	728		5	733	71.5
Firebaugh	2,083	1,253		60	1,313	63.0
Twitchell Island	1,000	501		13	514	51.4
Totals	15,267	8,993	29	258	9,280	60.8

[1] Bands collected at checking stations.
[2] Most clubs made an effort to collect and return bands.
[3] Voluntary return of bands.

results, presented in Table 5, showed that the number of individual hunters using each of these three areas averaged about 68 percent of the number of permits issued.

TABLE 5

Numbers of Individual Hunters and Permits Issued per Individual on Grimes, Natomas, and Staten Island Areas

Area	Number of state issued permits	Number of permits per individual hunter	Total individual hunters
Grimes	8,706	1.38	6,309
Natomas	10,297	1.56	6,601
Staten Island	3,184	1.34	2,376
Totals	22,187	1.45	15,286

Figure 2 shows the number of days hunted by individual shooters. Most hunters, 73.6 percent, used the area for only one day, and fewer than four percent hunted four days or more on one area.

Applying the average of 1.45 days hunted per individual to the total of 52,541 state-issued permits gives a calculated number of 36,235 indi-

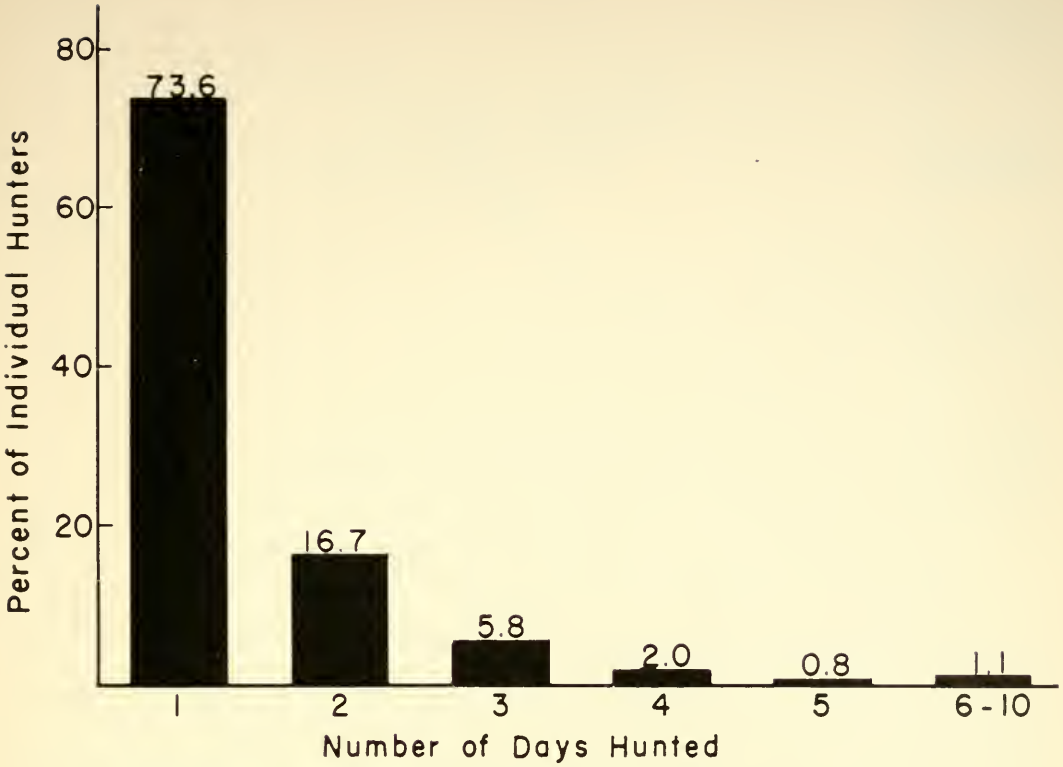

FIGURE 2. Number of days hunted on Cooperative Areas by individual hunters expressed as a percentage of the total sample number of hunters

vidual shooters using cooperative hunting areas. This figure has not been corrected for the unknown number of hunters that hunt on more than one area. However, it is believed that this duplication probably would be more than balanced by the number of landowners and their guests hunting on cooperative areas, which is not included in the 52,541 figure. Thus, it appears that approximately 20 percent of the 188,770 pheasant tag buyers hunted on cooperative hunting areas sometime during the 1951 season.

TRENDS

Figure 3 shows the trends of pheasant tag sales and over-all acreage, hunter use, and bag trends on cooperative hunting areas since this program was started. From 1949 to 1951 the total acreage has been increased 113 percent with gains of 33 percent in hunter use of the areas and 62 percent in the number of birds bagged.

The much greater proportionate increase in acreage has resulted from new cooperative hunting areas being added in poorer pheasant habitat where the numbers of hunters accommodated and pheasants bagged have been much less per unit of area than on the original areas. Also, adding more cooperative areas has had the effect of distributing hunting pressure more widely, so that the increase in hunter use has not paralleled the acreage increase of areas even in the better pheasant habitat.

Hunter success on the areas has increased approximately 25 percent. Less hunting pressure with approximately the same number of birds stocked per unit of area has resulted in a greater bag per hunter day of game farm birds and, on some areas, of wild birds.

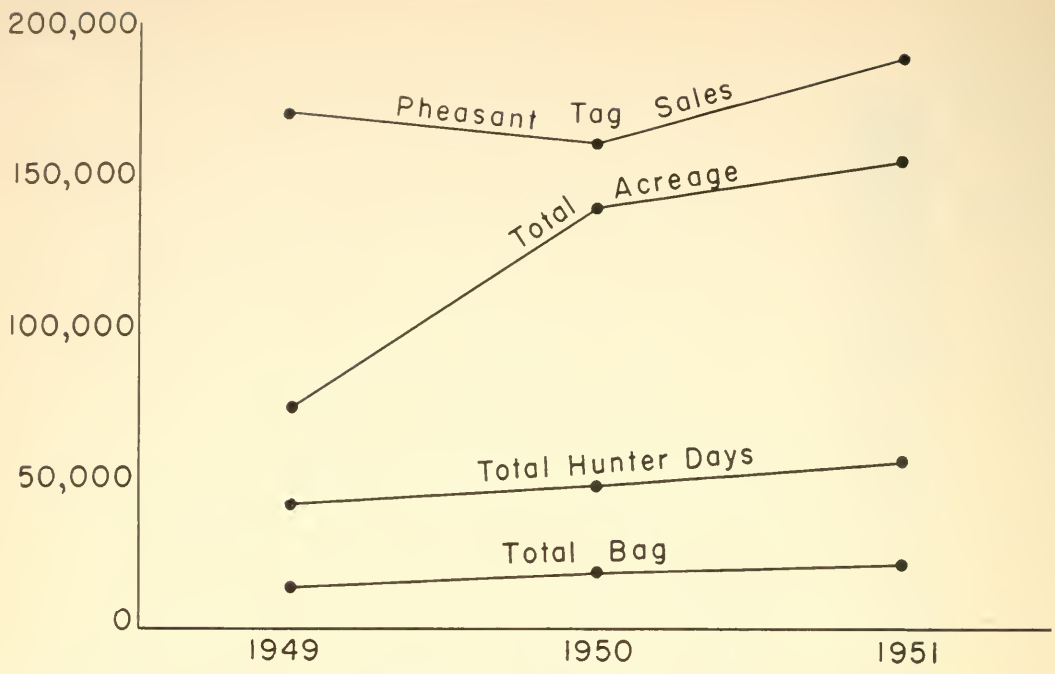

FIGURE 3. Cooperative Hunting Area trends and trend of pheasant tag sales, 1949-1951

The decrease in pheasant tag sales in 1950 was not reflected in lessened hunter use of cooperative hunting areas that year. It appears that the general trend of pheasant tag sales is upward, and that the cooperative hunting areas are aiding in furnishing these additional pheasant hunters with a place where they can hunt.

SUMMARY

1. Eleven cooperative hunting areas totaling 153,789 acres were operated by the Department of Fish and Game during the 1951 pheasant season.

2. A total of 21,781 pheasants was taken on the areas in 54,701 man-days of hunting. Success was 0.40 birds bagged per hunter day.

3. Wild birds made up 50.3 percent and game farm birds 49.7 percent of the total bag.

4. The 15,267 game farm birds stocked on the areas yielded a 60.8 percent return over-all, varying from a low of 27.0 percent from early releases in July to 70.4 percent from in-season liberations.

5. The total number of individual hunters using the areas was calculated to be approximately 36,235, nearly 20 percent of the number of pheasant tag buyers.

6. From 1949 to 1951 there have been increases of 113 percent in the total acreage of cooperative areas, 33 percent in hunter use of the areas, and 62 percent in the number of pheasants bagged.

LITERATURE CITED

Harper, Harold T., George Metcalfe and John F. Davis
1950. Upland game cooperative hunting areas. Calif. Fish and Game, vol. 36, no. 4. p. 404-432.

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REVIEWS

Amphibians of Western North America

By Robert C. Stebbins; University of California Press, Berkeley and Los Angeles, 1951; ix + 539 p., 5 color and 59 black and white plates, 35 figs. $7.50.

This book gives accounts of all the recognized species and subspecies of amphibians in western North America. Information as to distribution, habitat, behavior, food habits and reproduction is given for each species. The author tells the reader that "Tentative identification to species may be made by reference to the illustrations." This realistic approach and the convenient arrangement of the illustrations will make this book popular with the amateur naturalist as well as the professional herpetologist. The illustrations by Dr. Stebbins are in my opinion the best that have appeared on amphibians and excellent examples of what scientific illustration should be. The author has a knack for bringing out significant differences in his illustrations and figures. Distribution maps give ranges of all species and subspecies and localities where specimens have been collected.

I did not care for the arrangement of the table of contents and found the location of page numbers inconvenient and inconsistent. Except for these minor points of printing style I can find nothing in this book to rate adverse criticism.

This book is one that should belong to everyone interested in amphibians. It will undoubtedly stimulate an interest in these animals among those who even glance through the book and it will be a standard for many years to come.—*Wallace Macgregor, Jr., California Department of Fish and Game.*

Range Management, Principles and Practices

By A. W. Sampson; John Wiley and Sons, Inc., New York, 1952; xiv + 570 p., 111 figs. $7.50.

As investigations in the range management field ramify and intermingle with other related sciences, it becomes increasingly difficult for any one man to keep up with all the latest developments. As stated in the book under review, "The range manager, like the ecologist, leans on many fields of basic and applied science as background material in drawing plans for rational grazing land use." These fields include economics, veterinary science, animal husbandry, predator and rodent control, vertebrate and invertebrate zoology, big game management, animal nutrition, agronomy, ecology, plant nutrition, physiology, taxonomy, genetics, soil technology, irrigation, microbiology, geology, mineralogy, meteorology, and land-use planning and administration. Dr. Sampson has done a good job of integrating much of this material and presenting range management fundamentals in a well-written text.

Dr. Sampson's book, illustrated with 111 figures, is well documented. It is divided into four sections.

Part One, Range Management in Perspective, includes discussions of range management concepts, the world's grazing practices and problems, physiological principles and plant ecology as applied to range problems, physical and vegetal characteristics of our grazing lands, and the historical development of grazing in America.

Part Two, Native Range Forage Plants, discusses forage plants as a basis of range production, three tribes of range grasses, other native range grass and grasslike forage plants, and important western forbs and shrubs as stock-food plants.

Part Three, Improvement and Management of Range and Stock, is concerned with artificial reseeding and the establishment of irrigated pastures, natural reseeding and systems of grazing on western range, the control of noxious woody vegetation, management considerations common to ranges and range livestock, range conditions and trends as guides to better management, range utilization, range inventories and management planning, and the economic, physical, and social aspects of ranching.

Part Four, Protection of Land Resources and Range Livestock, includes chapters on protection of timber reproduction and the use of shade trees and shelter belts, stock-

poisoning range plants, their recognition and control, foraging and predatory wild life of the range, soil erosion and its control and administration of public grazing lands.

Although the text runs to 570 pages, it is obvious from a consideration of the scope of the subjects included that the treatment tends to be brief and principally concerned with fundamentals. As with any text of this character, one is apt to feel disappointed that the specialties in which the reader is interested are not given more attention. Thus the game manager, in the light of his knowledge of the numbers and economic importance of big game animals, and the importance to this resource of good range management, may wonder why the subject of big game range management is treated so briefly. And the range technician might wish for a fuller inclusion of some of the more recently developed range sampling methods. But taken in whole, Sampson's book is a usable and readable presentation of material that would need otherwise be gathered from extensive reading of articles, bulletins, and texts.—*William P. Dasmann, Game Manager, California Department of Fish and Game.*

Tropical Fish as a Hobby

By Herbert R. Axelrod; McGraw-Hill Book Co., Inc., New York, 1952; xiv + 264 p., illustrated. $4.

This amply illustrated book on tropical fish presents as its most useful feature a wealth of information in manual or handbook style. Organizing this broad field in such a complete and orderly manner lends ease to finding desired sections, and novices as well as the more experienced aquarist will find that the author covers quite adequately the principles of aquarium management, including the care and cultivation of the better known species of plants and fish.

Perhaps the most unusual feature of this book is a section written by Dr. Myron Gordon, geneticist, and James W. Atz, Assistant Curator of the New York Aquarium. Dr. Gordon discusses in one chapter the development of new varieties of tropical fish and in another chapter the nomenclature of fish. Following this, Mr. Atz provides a chapter exploding the myth of the balanced aquarium, explaining in some detail that fish and plants in an aquarium do not, in fact, balance each other in their production and consumption of carbon dioxide and oxygen. This section by Gordon and Atz is composed of reprints from various periodicals and makes an excellent guide for the advanced aquarist.

Although *Tropical Fish as a Hobby* does not attempt to stand as an exhaustive or comprehensive volume on the subject of tropical fish, it provides, for its size, an adequate coverage of the field in a concise, readable and well-organized manner and both the novice and the more advanced tropical fish hobbyist should find it useful.—*T. D. Westfall, California Department of Fish and Game.*

Game Birds and Mammals of California

By A. Starker Leopold; California Book Company, Ltd., Berkeley, California, 1952; 125 p., 29 plates, 21 figs. $3.

This laboratory syllabus was written for classes in wild life management at the University of California, but will also be valuable to anyone interested in California birds and mammals.

Each species is considered under four main subdivisions: identification, range and habitat, life history, and economic importance. The identification sketches, clear black-and-white drawings by Christman, emphasize the most distinguishing characteristics. Range and distribution maps are included for most of the species. These do not pinpoint areas where game is found, but show good general areas. Only the most important aspects dealing with management are discussed, including food habits, hunting and other interesting information. Many forms of wild life which are not considered at this time to be game are included and their relation to game, overlooked in many books, is brought out. Some birds and mammals not found in California are also listed, but emphasis is on the California species.

As this syllabus was written for an introductory course, it is brief and comprehensive, but many pertinent facts are included in the remarks. Any person desiring good general information on California birds and mammals will find this book interesting and informative.—*Edward R. Schneegas, California Department of Fish and Game.*

A Field Guide to the Mammals

By William Henry Burt and Richard Phillip Grossenheider; Houghton Mifflin Company, Boston, 1952; xxi + 200 p., illustrated. $3.75.

This, the fifth volume to be published in the Roger Tory Peterson field guide series, deals with the mammals of North America, north of the United States-Mexican border. Like its four predecessors it has been written not only for the professional worker in the field, but also for the many thousands of nature lovers whose enthusiasm is boundless, but nevertheless, whose time in the outdoors is limited by occupational pursuits.

The Peterson system of identification is based upon each animal's outstanding characteristics which can be readily discerned in the field, and these plus the general distribution maps make it possible for almost anyone to identify quickly as to species the animal observed. The breakdown stops there, as the authors felt, and rightly so, that there was a need for a simplified field guide and so left the complicated subspecies classification to the more technical publications. The many excellent colored plates are extremely helpful in correctly identifying the animal seen. Mr. Grossenheider's portrayals of the smaller mammals are truly works of art. His painstaking detail is especially valuable because the average naturalist is less familiar with them than he is with the larger animals.

Included for the person with an above-average interest in the subject of identification is a fine group of photographs of representative skulls together with their dental formulae. Of equal interest to those who spend considerable time afield are the simplified drawings of tracks left by many of the common animals. For the person who wishes to keep a record of all the species he has seen, a list of mammals is included so that each may be checked off when identified.—*John F. Davis, California Department of Fish and Game.*

The Bamboo Rod and How to Build It

By Claude M. Kreider; illustrated by Peter Kreider; Macmillan Company, New York, 1951; ix + 140 p. $2.95.

Few anglers who have used split bamboo rods have failed to admire the beauty of construction of this all-important item. Likewise, fishermen around campfires are always discussing various rod actions, name brands, and fishing techniques. Discussions of rod building are usually limited to the mention of closely guarded trade secrets possessed by rod makers.

"The Bamboo Rod" is one of the most complete books on amateur specialized construction the reviewer has yet seen. There is no reason why a few inexpensive tools, average skill, and this book should not turn "armchair angling" into a pleasurable sub-hobby. The author discusses completely all phases of bamboo rods from the raw cane to the completed product. The construction directions, hints and tips, and the general discussions will enable the hobbyist to construct the type and action rod he desires. However, the care and accuracy necessary in fitting parts of the new rod could be stressed more fully. The chapters following those on general construction of the glued-up strips will be of value to many anglers who only wish to repair, refit, and refinish a favorite rod.

Although the book is primarily intended for the man who wishes to construct a bamboo rod, valuable information on the various types and actions of rods is included. This information will clarify some of the mysteries and myths of rod nomenclature. —*Chester Woodhull, California Department of Fish and Game.*

The Best Loved Trees of America

By Robert S. Lemmon; Doubleday and Co., Garden City, New York, 1952; 254 p. $3.50.

Robert S. Lemmon, former managing editor of "House and Garden" and author of "How to Attract Birds" and numerous magazine articles, here presents to the lay botanist and naturalists an informative and non-technical book that gives detailed descriptions of each of 59 of the most common or picturesque trees of America. Each description includes data for identification of the tree, a summary of its life history, a list of its commercial uses and values, the limits of its native range, and, among other interesting items, recommendations for landscaping—where and when to transplant and precautions that should be taken to insure greatest success.

An outstanding feature is the 293 well chosen photographs depicting the floral and fruiting parts, bark, and over-all form of the tree in its native habitat, including summer and winter photographs of the deciduous species. One may become somewhat

bothered, however, by the fact that there are no captions with the illustrations. This omission sometimes necessitates thumbing through several pages to the head of the section on that species. Incidentally, the species are not arranged in any taxonomic or geographic grouping.

The author has taken care in presenting species native to each section of the continent. Of the 58 indigenous species 36 are native to the region east of the Rocky Mountains, but 30 of them have been introduced to the West Coast where they are now commonly found.

Considering the difficulties in assigning a single common name to a specific organism, it is not surprising that a few discrepancies occur. For example, there is an error in the contents where the author used the specific name of *Quercus crysolepis* (canyon or maul oak) for the California live oak, which is *Q. agrifolia*. The text and illustrations describe *Q. agrifolia*. A more serious error was made when the author described and illustrated the American beech (*Fagus americana*) and called it *F. sylvatica*, which is the European beech. Also, the particular will notice that the author states that there are two species of live oaks in California whereas there are at least four.

The naturalist, lay botanist, and landscape gardener will find this book interesting, useful and authoritative. For the research worker or the game manager in the field, it is of little value though it does have a place as a reference book for those especially interested in silviculture.—*Daniel J. Miller, California Department of Fish and Game.*

Flowers of the Southwest Mountains

By Leslie P. Arnberger; drawings by Jeanne R. Janish; Southwest Monuments Association, Santa Fe, New Mexico. 1952; 109 p. $1 (Paper).

This is the "Mountain Book" of a triad of booklets which are designed to aid layman in identifying the more conspicuous plants of the southwestern United States. The first, "Flowers of the Southwest Deserts," introduces plants of the hot, dry deserts; the second, "Flowers of the Southwest Mesas," covers the plants of the Pinyon-Juniper Woodland country which ranges from 4500 to 7500 feet in elevation; the third and last of the group "Flowers of the Southwest Mountains" deals with the plants found from 7500 feet up.

There are two steps in the identification of the various plants: (1) a color key leads one to a broad group, and (2) detailed drawings to specific identities. Trees are identified by form only. The inherent weakness of a color key is acknowledged. However, this is partially overcome by using broad color groups, six in all, thus tending to eliminate the confusion resulting from different interpretations of color. The drawings are excellent. Minute details are shown with simplicity and clarity. By illustrating various stages in the plant's life history, identification during periods other than the flowering is facilitated.

The background material includes such items as origin of names, uses by wild and domestic animals, and uses by man. This type of information increases the booklet's value by stimulating interest beyond the learning of labels and also aids in future recognition.

This reviewer found that the booklet was of considerable use in areas other than the southwest mountains. During a recent trip to the mountains of Northern California and Southern Oregon, many of the flowering plants were effectively keyed out, at least to genus. The identification chart for evergreens worked equally well.

Visitors to the high mountain regions of the west will find their trip enriched by the use of this booklet.—*Leo Pinkas, California Department of Fish and Game.*

Charley Cottontail

By R. W. Eschmeyer; Fisherman Press, Oxford, Ohio. 1952; 50 p. $1.50 cloth; $.50 paper.

The latest in this excellent and authoritative series of children's books written by a foremost conservationist. Other recent titles include "Freddy Fox Squirrel" and "Bobby Bluegill."

REPORTS

FISH CASES

April, May, June, 1952

Offense	Number of arrests	Fines imposed	Jail sentences (days)
Abalone: Closed season; undersize; possession out of shell; using illegal instrument; failure to show on demand; no license; failure to have accurate measuring device	206	$6,934 00	
Angling: No license; 2 lines and poles; failure to show license; operating 4 set lines; closed season; no non-resident license; possessing 3 spears within 300 feet of stream; fishing in closed area; operating limb line; false statement to obtain license; set lines; night fishing; operating fish trap; using 2 poles and and handline; illegal fishing equipment; snagging; using another's license; using compressor to take fish; angling within 150 feet of lower side Mendota dam; transferring angling license; unattended rod; angling too near fishway; angling in closed spawning waters; operating 7 lines; chumming with vegetable matter; taking game fish with net	652	8,041 50	63
Bass: Taking black bass without license in closed season; taking in refuge; using 2 poles; overlimit black bass; possessing striped bass in bait store; using 2 lines; taking undersize; taking at night; no license; overlimit; using 3 lines	34	885 00	
Catfish: Using 2 poles; using 6 setlines; overlimit; night fishing; no license; operating fish trap	16	180 00	
Clams: Cockles, overlimit, no license, closed season, undersized; big necks, no license, overlimit; pismos, undersized, overlimit, no license, closed season, digging in preserve, failure to bury undersized, out of shell; gaper, overlimit; Washington, overlimit; razor, overlimit	101	3,929 00	60
Commercial: No license; bringing fish ashore in condition in which size and species could not be determined; no importer's license; failure to record species on market ticket; illegal use roundhaul net; possessing illegal dragnets; agent knowingly selling citizen license to aliens; using roundhaul net and possessing fish Dist. 19A; possessing undersized salmon; selling undersized yellowfin tuna; possessing striped bass on commercial boat; no party boat permit and failure to keep records; undersized crabs for sale; allowing crabs to deteriorate and waste; failure to show catch; taking crabs closed area; selling fish without license; illegal packing for pet food	57	4,290 00	
Crab: Undersize	8	180 00	
Frog: Closed season	3	30 00	
Lobster: Using trap in closed area; closed season	2	75 00	
Pollution: Sawdust, oil, tin cans and hog swill, mill refuge, rotary mud	11	1,050 00	
Salmon: Spearing and blocking stream	1	50 00	
Sturgeon: Taking full protected fish	1	25 00	
Sunfish: Closed season; overlimit; no license; alien taking with illegal license; using 2 lines; operating fish trap	51	1,445 00	
Trout: Overlimit; failure to show license; closed season; closed stream; unattended rod; no license; using 2 rods; set line; possessing spear and attempting to take with artificial light; taking within 150 feet of dam	96	3,340 00	
Yellowtail: No license	1	10 00	
Totals	1,274	$31,364 50	123
Sale of seized fish		6,243 55	
Grand total		$37,608 05	

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GAME CASES

April, May, June, 1952

Offense	Number of arrests	Fines imposed	Jail sentences (days)
Deer: Possessing closed season; allowing dogs to run deer in closed season; taking spike buck in closed season; taking 2 spotted fawns (alive); taking doe; loaded 22 in car; spotlighting; Calif. resident possessing deer on Utah license; taking deer at night; possessing female deer	40	$3,870 00	1,515
Deer meat: Possessing in closed season; possessing unstamped meat	34	3,790 00	160
Dove: Possessing closed season; taking closed season	4	75 00	30
Duck: Taking closed season; shooting from power boat; late shooting; transporting from North Dakota without permit	11	365 00	----------
Hunting: Loaded gun in auto; hunting without license; removing trap belonging to licensed trapper; disturbing State trap line; hunting in closed area; trespassing; failure to show license; shooting from road; using artificial light; hunting on cooperative area without permit	72	1,910 00	----------
Mudhen: Taking closed season; using 22 rifle	2	25 00	----------
Nongame animal: Killing mountain sheep	1	250 00	----------
Nongame birds: Taking robins, seagulls	2	45 00	----------
Pheasant: Failure to tag; possessing closed season; taking with 22 rifle in closed season and from public road; taking hen pheasant; operating game bird farm without license and failure to release proper number of pheasants	17	820 00	2
Pigeon: Taking in closed season; loaded gun in car; no license	5	160 00	----------
Quail: Illegal importation from Mexico; taking with 22 rifle; failure to show license; closed season	2	125 00	----------
Rabbit: Night hunting; closed season; no license; shooting in safety zone; loaded 22 in auto; artificial light; shooting from auto	45	1,527 50	50
Totals	235	$12,962 50	1,757

SEIZURES OF FISH AND GAME

April, May, June, 1952

	Number	Pounds
Fish:		
Abalone	644	91½
Bass	150	50
Catfish	416	----------
Clams	364	----------
Crab	138	7,771
Halibut	2	----------
Mackerel and sardine	----------	348
Salmon	23	----------
Sole	14	----------
Sturgeon	1	----------
Sunfish	544	----------
Trout	662	----------
Yellowfin tuna	----------	8,748
Yellowtail	2	2,980
Game:		
Deer	21	----------
Deer meat	----------	258
Dove	12	----------
Duck	15	----------
Mudhen	2	----------
Nongame birds	2	----------
Pheasant	12	----------
Pigeon	4	----------
Quail	2	----------
Rabbit	52	----------

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